

KEEPING WARM IN NEW ENGLAND:
A History of Residential Heating
from Colonial Times

by

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ABSTRACT

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This thesis explores the development of residential heating methods in New England from the days of the first settlers to the introduction of equipment that is commonly used today. It shows the transitions from wood to coal in England and the U.S. and the later conversion from coal to oil and gas, exploring the reasons behind each of these changes.

The development of heating equipment is traced from its earliest stage, the wood burning fireplace. Chapters show the major types of equipment used at each stage of development and the advantages and disadvantages of each, including fireplaces, coal grates, stoves, and central heating: hot air, hot water and steam. Special attention is paid to the developments that made each type of equipment available to large numbers of people at low cost.

The early colonial house and its massive central fireplace is studied, considering its design as a response to the New England climate. The reasons why that type of house stopped being built are examined, as is the impact that those developments had on modern construction.

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PREFACE

Reduced to its simplest form, the house is nothing more than an enclosure to protect human beings from the adverse conditions of their natural environment. Its basic elements are few: a roof and walls to protect against the intrusion of rain, snow and wind; some means for gaining access to the interior; and a source of heat to provide some degree of comfort.

To these essential components people have over the years added devices to provide for various other needs and desires: penetrations to provide light, ventilation, and view; interior divisions to provide privacy and separation of activities; and appliances and furnishings to meet the needs of cooking, eating, sleeping, bathing, elimination, recreation and countless other personal and social activities. The form and nature of these modifications and, indeed, of the basic shelter itself, are shaped by and in turn give shape to the whole set of social, aesthetic, historical and spiritual considerations that elevate the house from merely shelter to a symbol, to oneself and others, of one's being.

But, stripped of all the attitudes and devices that have been added over the years, the essentials of shelter and warmth remain as the fundamental reasons for the house's existence. It is the element of warmth, particularly the means and devices that have been used to provide warmth in New England, that forms the topic of this thesis.

The thesis begins by examining the upheaval in the fuel situation in England at the time when the first colonists set sail for America and how the shortage of wood caused changes in building and heating methods.

Chapters II and III look at the houses that the settlers built in New England and how their form derived from traditional English building methods, was influenced by the rigors of this region's climate.

Particular attention is paid to the form and construction of the massive central fireplace that was the heart of the early house and the focal point of indoor domestic life. Finally, the influence of outside forces -- social pressures and the advent of style -- conspired to bring an end to the central chimney, and the impact of that passing is also discussed. Chapter IV discusses an other factor that brought changes in the fireplace: the increased understanding of how fireplaces work.

Chapters V and VI trace the development of two of the first forms of heating appliance to come into use: cast iron stoves and coal burning grates. Particular attention is paid to the innovations of the "Franklin stove" and its popular derivatives. Types of closed stoves that saw widespread use are also examined.

Chapters VII, VIII, and IX trace the development of the two major forms of central heating; the hot air furnace and steam and hot water systems. The emphasis in these chapters is on the significant technical innovations that brought this equipment from its most primitive forms to the state in which it could become widely used. Also discussed are the operating procedures necessary with these systems and the burdens that these placed on the homeowner.

The thesis concludes by exploring the revolutionary changes that took place in residential heating in the period after World War I and the unique set of conditions that brought about such a sudden and complete change of affairs. These changes were particularly important for not only did they at last free people from the daily labor of attending to their heating needs, they also involved a switch away from the one fuel that was, and is, known to be in abundant supply.

While the emphasis in the thesis is on the technical improvements of heating apparatus, attention is paid throughout to the factors of economics, convenience and fuel supply that both brought about the changes and eventually made them available to large segments of the population.

To my knowledge no one has ever written a comprehensive history of residential heating. Reyner Banham voices the same complaint in the introduction of his Architecture of the Well-Tempered Environment, but the focus of that book is more analytical than historical and deals mostly with more recent developments on the realm of environmental control. Of course the potential scope of a history of residential heating is enormous. At the outset I attempted to make the task more manageable by limiting it to a particular region, New England, and to a particular time span, namely, the course of events that led up to the current, commonly used methods of heating. Since the major purpose has been to try to understand how we got where we are today, relatively minor events in the field such as experiments with electric and solar heating, though potentially of great importance, have been excluded.

Still, the present work cannot hope to be considered more than a beginning exploration of the history of residential heating in New England. The history of heating and the development of a heating industry is inextricably tied up with the whole history of the industrial, economic and social growth of the region, and, in more recent times, of the entire nation. I have attempted to point out the most significant events where they occur, but to follow most of these threads in detail was clearly beyond my intended scope or the time available to fulfil it.

What follows then, is basically a history. Hopefully a knowledge of the events that have brought us to the current state of affairs can bring some understanding of the problems and processes that must be faced if new, more efficient methods of house heating are to be brought into widespread use.

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CHAPTER I

THE COLONISTS' HERITAGE:

Home heating in England and Europe 1600-1800

The English climate that the colonists left behind was by no means the testing adversary that they were to find in the New World. The English were accustomed to a moderate climate, with stable temperatures, and no extremely cold winters or hot summers. Precipitation, while similar in quantity to that in the Massachusetts area, was more evenly distributed; snows and droughts were rare; tornadoes and cyclones unknown.

The typical English village cottage of the period (Fig. 1) was a timber frame structure of one or two stories with a chimney and fireplace at one end. The spaces between the timber frame members were filled in with plastered brickwork or wattle-and-daub (a mixture of woven sticks and mud). This technique had evolved as wood for building became increasingly scarce. Material for thatch was in plentiful supply, and the traditional English thatched roof was more than sufficient to protect the occupants from the gentle English rains. The open fire on the hearth provided warmth.

The nature of that open fire, though, was in the process of undergoing a profound change during the early 1600's. England had been short of timber for some time and in the sixteenth century demand so exceeded supply that she virtually ran out of wood. The reasons for this were several. The burgeoning process industries of iron, lead and glass demanded the cutting of vast forest areas to satisfy their appetites for fuel; as early as the tenth century the charcoal burners had made



Fig. 1: Half-timbered English village house.

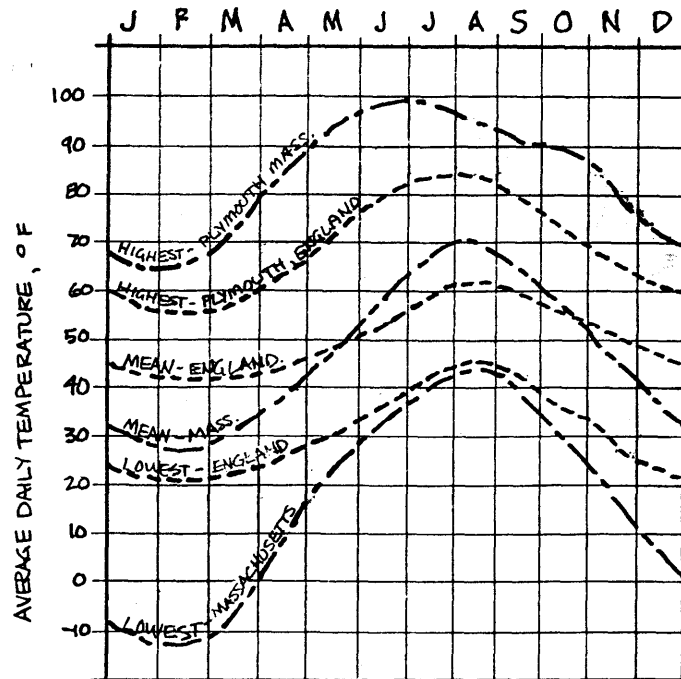


Fig. 2: Comparison of average daily temperatures in Plymouth, Mass., and Plymouth, England. Source: Fitch, James M., American Building and the Forces that Shape It, Boston: Houghton Mifflin, 1948, p. 11.

such inroads on the forests that their output was limited by law.¹
In 1615 King James I discovered that a single glassworks was burning
400,000² pieces of wood a year to get potash; he promptly banned the
practice. The great British Navy of course consisted entirely of
wooden ships; that alone placed a significant demand on the wood supply.
The forest lands that were open to entrepreneurial lumbering became
increasingly less productive as they were repeatedly cut over. Wood
had to be transported further and further as the forests receded. What
new forest growth there was was more profitably used as lumber, increasing
the scarcity of wood as a fuel. Even for use as a building material
the remaining forests became off limits to the common people, who
increasingly had to live in huts or cottages made of sod or stone.³
The price of firewood increased 800% between 1531 and 1632, while coal,
in minor use for heating for some time, remained relatively cheap. These
factors hastened the adoption of coal as the basic heating fuel in
England and the widespread use of coal grates.⁴

Coal had been mined and used in England as early as 850 a.d. but
was not really accepted as a domestic fuel until the start of the 17th
century, when the lack of wood made its use inevitable.⁵ The early
prejudices against coal were that it smelled strange and gave less light
than a wood fire. The existing hearths that served so well for wood
fires were not suited to burning coal; they smoked and did not burn well.
Still, the situation was irreversible. Fireplaces were reconstructed
to be smaller and shallower and were fitted with grates to contain the
coal fire and to admit air to it from below. Soon the simplicity,
concentrated heat and staying power of coal became recognized. In time
the coal fire with its mound of even, red-glowing coals developed
favorable associations and then an aesthetic of its own.⁶ The grates
were installed one to a room, with a network of flues leading to the
roof and the profusion of chimney pots that became one of the most

striking features of British cities. Another striking feature that was more directly a product of coal was the soot that poured from the chimneys and blanketed the city. This was the result of incomplete combustion of soft coal and was a problem that would vex grate and fireplace designers for centuries.

The English suspicion of the "fyre secret felt but not scene" and love of the open fire left their heating technology somewhat backward in comparison to that found on the continent, where fuel was not so abundant or cheap as in England. In northern Europe closed stoves of varying designs were in widespread use. With a long stovepipe these would allow far more of the heat of combustion to remain in the room than would the English grate. The closed stove created no drafts and gave off no smoke or dust. They did, however, tend to give the air a burnt and sulphurous smell, partly due to dust burning off the hot iron, and the English, unaccustomed to this, never accepted closed stoves.⁷ Even the later (early 19th century) Scandinavian practice of building closed stoves of masonry to eliminate the bad effects of heated iron failed to find favor in England. (Such stoves were in a way quite sophisticated. Charged and lighted but once a day, a damper in the chimney would be nearly closed after the moisture in the wood or coal had been driven off, thus maintaining a long-lasting, slow-burning fire. The large mass of the unit would heat and continue to warm the room long after the fire had gone out.)⁸

Count Rumford, the noted and notorious heating expert whose work will be more fully discussed later, was especially distressed by the inadequate heating facilities in Britain as opposed to the continent. He felt that the demonstrably better health of the Germans, Russians and Scandinavians was linked to the warmth of their houses, as they emerged from far warmer houses into far colder temperatures with no ill effects.

"There cannot surely be anything injurious to health in the genial warmth of 60° - 65°," Rumford wrote in his 1796 essay, "Of the Management of Fire, and the Economy of Fuel," a classic that nevertheless apparently failed to excite or influence conservative Britons.⁹

Having taken this account of heating in England somewhat beyond the colonial period it is now necessary to return to the intrepid settlers at Plymouth, who would have gladly accepted the conditions that so distressed Count Rumford. In Plymouth, Massachusetts, the colonists found a climate whose annual cycle was far more severe than what they had known in Plymouth, England. The temperature spread from July to December were more than twice as great, as the chart (Fig. 2) shows, and the heavy snowfalls, long freezes and enormous gales were all new experiences for the settlers. They were forced to "burrow themselves in the earth for their first shelter under some hillside, casting the Earth aloft upon timber; they make a smoky fire against the Earth on the highest side; and thus these poor servants of Christ provide shelter for themselves, their wives and little ones, keeping off the short showers from their lodgings but the long rains penetrate through to their great discomfort in the night season."¹⁰

CHAPTER II

SHELTER IN THE NEW WORLD

The earliest settlers, though arriving here as part of planned, commercially inspired expeditions, were often poorly equipped to deal with the adverse conditions they found, not having among them carpenters or masons or even an adequate supply of building tools, a situation partly the result of inaccurate and glowing accounts of the New World which the earliest explorers had brought back.¹

In the Massachusetts Bay Colony the earliest shelters (Fig. 3) were nothing more than poor imitations of the Indian long houses in use throughout New England (Fig. 4). They were made of saplings and tree branches, driven into the ground, then bent over and tied at the top and covered with thatch, entirely penetrable by the winter winds. In the crudest shelters the first fireplace was nothing more than a circular hearth on the floor, with a hole in the roof above to allow the smoke to exit. More common was a crude fireplace and chimney at one end of the structure, made of logs laid up cob-style and chinked with clay to provide some degree of fire resistance.

The obvious inadequacy of these primitive shelters was quickly recognized and dealt with. Certainly the raw materials were available, for the land was virtually an unbroken forest. Accounts of the early settlers tell of huge trees: pines up to six feet in diameter and 247 feet high; hardwoods 100 to 200 feet high were commonplace. An old saying had it that when the Pilgrims landed a squirrel could go all the way from Plymouth to the Mississippi River without touching ground, eating nuts as he leaped from one tree to the next.²



Fig. 4: Indian long house.

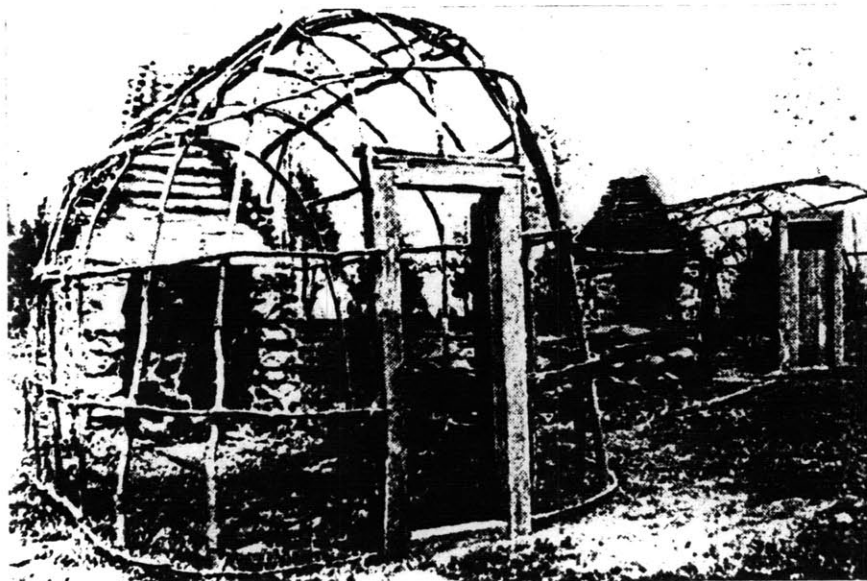


Fig. 3: Skeleton of first settlers' shelters in the Massachusetts Bay Colony.



Fig. 5: Timber frame dwelling built by settlers at Plymouth, Mass.

A typical braced frame of massive timbers built around an equally massive central chimney. This one provides an overhang in front, with four decorative drops. (Drawing from Norman Isham and Albert Brown, *Early Connecticut Houses*.)

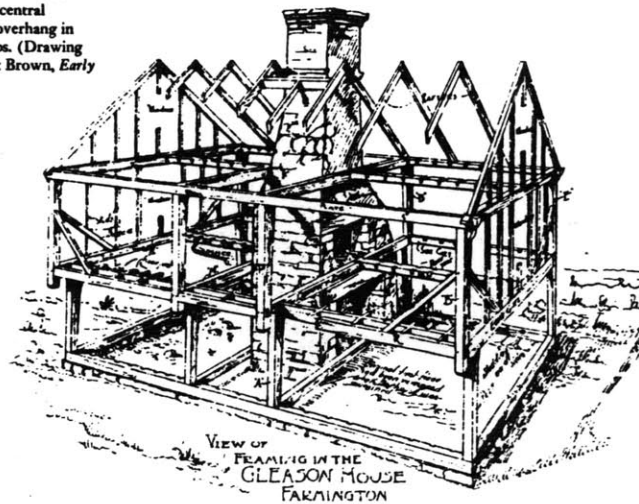


Fig. 6: Though from a somewhat later period, this drawing illustrates the basic elements of the timber frame and the location of the central chimney in the house.

Skilled building craftsmen soon joined the first settlers, bringing with them the tools necessary to convert the vast supply of raw material into usable building products. Sometimes the tree trunks were squared into beams with a broadaxe, but the pit saw was adopted from the beginning, as both the English and Dutch were familiar with the technique. As the number of colonists increased that method proved too slow to meet the great demand for building materials and water-driven mechanical sawmills were soon established (sawmills were known in England but had been outlawed for fear of technological unemployment among the sawyers). Fitch reports that the first of these were in operation as early as 1631, but Mixer and others put the time a decade or so later.³ Bricks were made from the clay found by the ocean and in river beds. By 1630 bricks were being produced commercially near Chelsea, Mass.

For some time it was a popular myth that the primitive huts were succeeded by log cabins. In fact log cabins were built by the Swedes who settled in New Jersey around 1638 and their use did subsequently spread, but there was nothing in the tradition or experience of the English settlers to suggest such a structure to them. While such houses might well have proved the most practical for the climate, the colonists didn't build them for the simple reason that they had never seen one.⁴

The houses that the colonists did build were quite naturally based on the British half-timbered cottage that they knew so well (Fig. 5). Though they evolved somewhat differently in the various colonies, the basic cottages were pretty much the same. The plan of the house was rectangular, nearly square, with a large stone chimney (at first laid up with clay and straw, as mortar was not available for a time) built into and supported by a stone end wall as its most important feature. The houses were generally one story with a steep roof to shed water. The resulting attic had a window in the end opposite the chimney and was

reached by a ladder placed to one side of the chimney. The structure of the house, in the English tradition that had evolved over several hundred years, was of heavy timbers, generally oak, the attic being supported by the "summer" beam which was carefully fitted into the end plate of the frame and the chimney girt (see Fig. 6). The whole weight of the structure was carried to the sills by heavy corner posts, themselves braced diagonally. The sills were laid on a thin foundation of stones. Apparently the earliest houses had only an earth floor.⁵

Despite the vast quantities of wood available, the colonists first built their houses in precisely the manner that had been used in wood-starved England. The timber frame was infilled with wattle-and-daub or brick nogging (Fig. 7) and the roof was thatched. Unfortunately, that form of construction couldn't survive the New England climate. The abrupt and extreme weather changes produced rapid expansion and contraction of the brittle infill, causing it to deteriorate quickly.⁶ The thatch suffered under the tons of New England snow and was dried to tinder under the long, hot dry spells of the summer.⁷

The first step in providing a more durable and weather-resistant "skin" for their houses was, probably with some reluctance, to cover the nogging with a wood siding that would shed water and not be subject to cracking. The technique adopted varied among the different settlements. In northern Massachusetts and other localities the narrow clapboard (Fig. 8) was preferred, nailed to the frame with hand-wrought nails. (The term "clapboard" is derived from "clay-board", for the boards were originally used to cover the clay infill.) Hand-rived wood shingles, more capable of withstanding heavy rain and slightly less prone to fire, had replaced thatch as a roof covering, and on Nantucket and eastern Long Island these were preferred as a wall covering as well.⁸

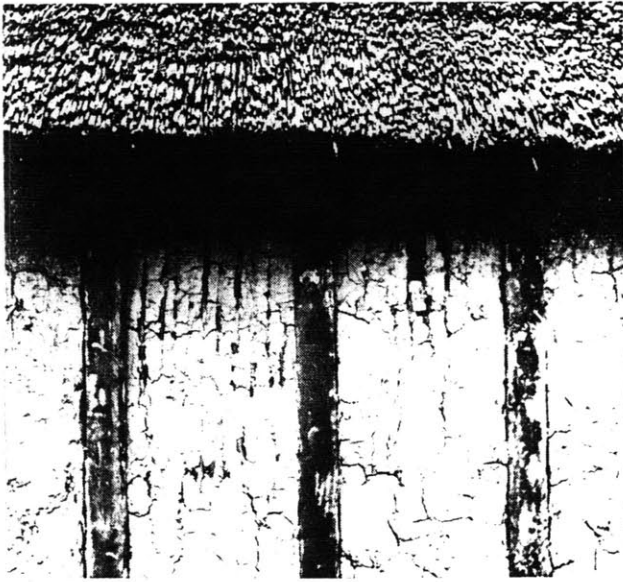


Fig. 7: Wattle-and-daub infill between framing members. This method did not stand up well under exposure to New England's harsher climate.



Fig. 8: The first hand-riven clapboards provided a weather-resistant skin for the house.

Studding was introduced to the framework at first only to give the carpenter something to nail the siding to. Gradually the brick or wattle-and-daub infill disappeared entirely in favor of plastered interior walls, which could also be supported by the studding.⁹ The insulating value of the infill material was recognized, however, and the void between the inner and outer wall surfaces was often filled with bits of shale or straw.¹⁰

The Waite-Potter House (Fig. 9) in Westport, Mass., though built later in the period (1677), is typical of the construction of these early houses. The original stone end of the old house, supporting the stone chimney, is visible above the roof of the later ell. The fireplace opening inside is nearly as wide as the house and faces the single room which is 18 feet square. The chimney itself is laid up with mortar made of crushed sea shells.¹¹

Large families were the order of the day in the Puritan communities and expansion of the single room cottage became imperative. In Rhode Island this evolution retained the traditional end chimney and thus was upward. The resulting type of structure is illustrated by the drawing of the Olney House in Sakesakut, R.I. (Fig. 10).

In Massachusetts the expansion to meet growing space needs was generally met by lateral rather than upward extension of the basic house. Many houses that started as one-room cottages with an end chimney had another room added to leave a central chimney. Whether the extension was added on or a part of the original structure, the floor plan is basically the same, with its two rooms flanking the massive central chimney with its back-to-back fireplaces. The entry was at the center of the front wall, the stair to the attic opposite it, against the side wall of the chimney (Figs. 11 and 12). The Jethro Coffin House on Nantucket, built in

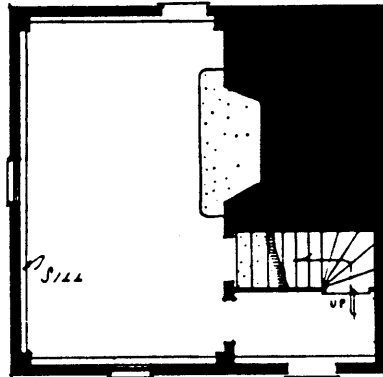


Fig. 11: Floor plan of basic one room house.

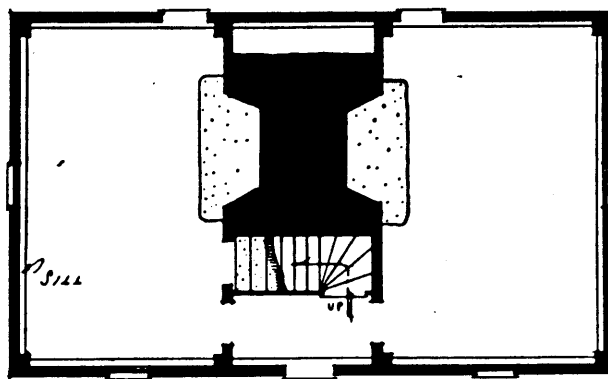


Fig. 12: Floor plan of two room house with a large central chimney

1686, is fairly typical of this form of construction (Fig. 13). The lean-to at the rear, having its own fireplace drawing through the central chimney, is part of the original building, though that was not always the case in this type of house.¹² Very often the lean-to would be added later, yielding a floor plan like that shown in Fig. 14. A lean-to that has been added can usually be identified by its roofline, which usually did not match that of the original house (Fig. 15).

Before the Coffin House was built a style of building larger houses had developed in Massachusetts and Connecticut. Originally intended for use by the pastor and his family or the larger land-owner or military leader of a district, this style became well-nigh universal toward the beginning of the eighteenth century. The Parson Capen House (Fig. 16) in Topsfield, Mass., is typical of these houses. It has four large rooms - two on each floor, one on either side of the chimney, and a long attic. The huge chimney structure contains a large fireplace for each of the four main rooms.¹³ A simpler, less decorated example of the same form of house is the John Alden house of Duxbury (Fig. 17). These houses have no lean-to at the rear, the addition of which was the logical sequence of evolution for this type of house. That development is typified by the John Dillingham house, West Brewster, Cape Cod (Fig. 18),¹⁴ which is essentially the Alden house duplicated, with the lean-to added.

THE ADVENT OF STYLE

During the eighteenth century American domestic architecture began to undergo some profound changes -- changes that reflected, and resulted from, larger changes taking place in the society as a whole. The Puritan village idea was losing its focus as the population spread to the outskirts of the towns and as the British Crown asserted its grip



Fig. 13: The Jethro Coffin House on Nantucket Island.

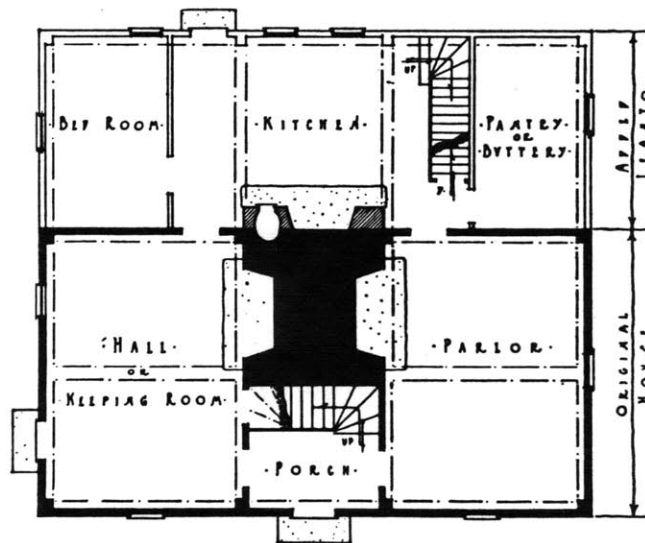


Fig. 14: Plan showing arrangement of rooms in "lean-to" addition at rear of typical house.



Fig. 15: Lean-to's built as part of the original house (right) can be distinguished from those added later (left) by the shape of the roofline.



Fig. 16: The Parson Capen House in Topsfield, Mass., typical of the larger houses built in the late 1600's.



Fig. 17: The John Alden House in Duxbury, Mass.



Fig. 18: The John Dillingham House, West Brewster, Mass.

on colonial government. The vast resources of the region spawned a vigorous foreign trade that made many people rich and caused businesses to thrive. Class distinctions began to become more distinct.

The demands of style to which the new wealth was becoming accustomed could no longer be contained within the traditional low-ceilinged two or four-roomed colonial house. The search for the fashionable turned the wealthy to the styles of Europe and particularly London, where the classical designs of Palladio were taking hold popularly in what became known as the Georgian style. The multitude of pattern books to come off the presses of London in the early 1700's quickly found their way to America and assured that the Georgian style would take hold in the colonies. The style showed itself here in a strictly observed symmetry and in wooden detail work often applied like an afterthought (which in some cases it was) to the strong, simple shape of the New England house (Figs. 19 and 20).

The most significant change, however, came in the basic layout of the house, which became much more spacious and formal. Houses in the new style were two rooms deep upstairs and down with ten or twelve foot ceilings on the ground floor. The massive central chimney disappeared to make way for a grand hall and stair running the depth of the building. On either side of the hall lay, in plan at least, a replica of the early houses: two rooms separated by a chimney that provided each with a fireplace (Fig. 21). The fireplaces themselves were smaller and more elegant (Fig. 22), with narrower flues, anticipating the improvements to be suggested by Count Rumford later in the century, and threw more heat into the room and less up the chimney. Still, the size of the house and placement of the fireplaces required the maintenance of several fires to heat the whole house, and gone was the huge mass of the central chimney that acted as a heat reservoir for the entire



Fig. 19: Pitt's Head Tavern, Newport, R.I.,
an example of Georgian-style decoration
applied to - large central-chimney house.



Fig. 20: Georgian-style house with two chimneys in
Yarmouth, Mass.

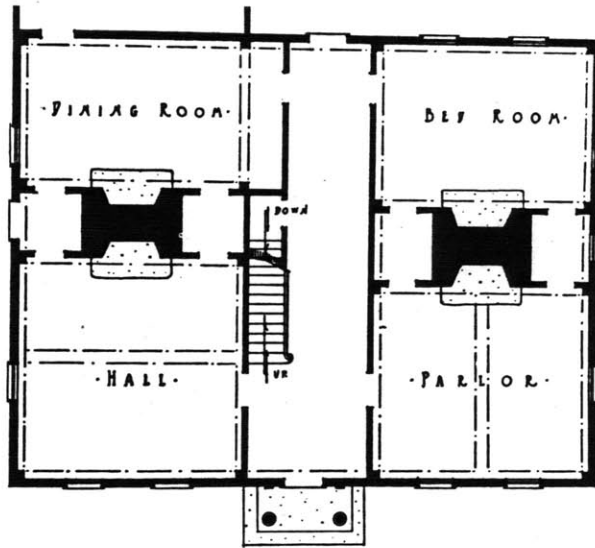


Fig. 21: The plan of early Georgian houses was essentially that of two smaller central-chimney houses separated by a hallway.

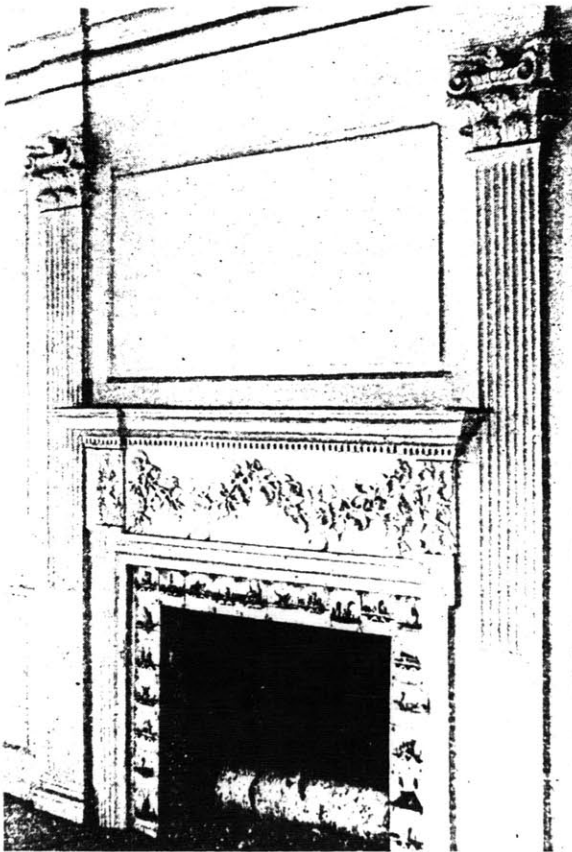


Fig. 22: Fireplaces became smaller and more elegant during the Georgian period.

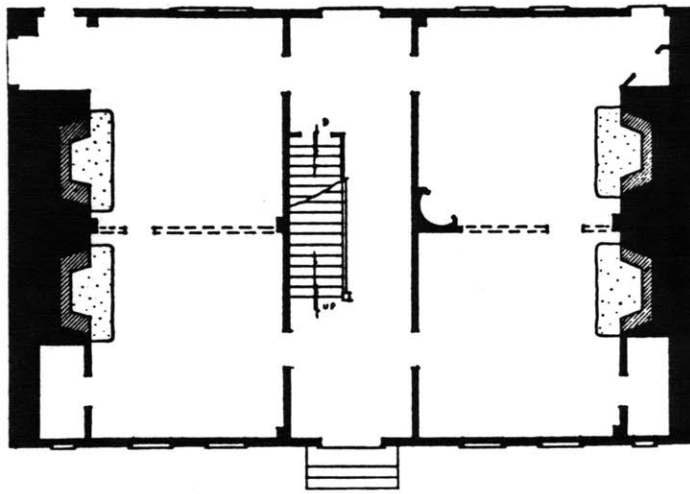


Fig. 23: Later Georgian houses had the fireplaces removed to the end walls to create a more open first-floor plan.

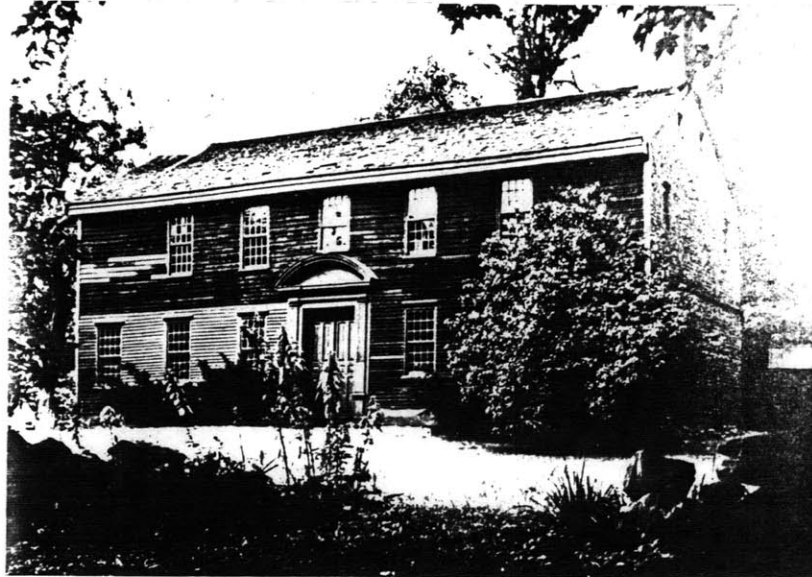


Fig. 24: A brick-ended house following the floor plan above.

structure. And even after the introduction of the heating stove, the
central hall and stair still had no heat at all.¹⁵

Later designs moved the fireplaces and chimneys to the end walls of the house to provide more freedom in arranging the floor plan of the rooms (Fig. 23). Such houses commonly had the entire end walls built of brick (Fig. 24), and the next logical step was to build the entire house of brick.

The advent of "style" marked a turning point in American domestic architecture from which it has not yet recovered. The early house, directly derived from those found in the common experience of the settlers from working-class England, had assumed a form that was influenced heavily by the characteristics of the New England climate. While crude as an efficient heat source, the central hearth and chimney were cannily designed to absorb the fire's heat by day and radiate it back to the house at night. It also provided an all-important focus for the layout of the house and the pattern of activities within it. The size of the house was limited by the distance that heat could be effectively radiated from the fire, and the low ceilings served to conserve what heat the fire did throw off. The southern orientation of many houses, deliberately chosen to admit the greatest amount of light through windows that were limited in size by the scarcity and expense of glass, had important thermal benefits as well, as did the placement of the lean-to addition on the northern side. The broken shale or straw that replaced the earlier brick nogging in the void between the inner and outer wall surfaces provided a primitive yet beneficial form of insulation. Even this practice was to be lost in time, not to reappear until early in the twentieth century.

As homeowners became more concerned with style and houses became more and more expressions of the tastes or pretensions of their occupants,

thermal considerations took a back seat as determinants of house form. While fireplaces themselves became slightly more efficient, their deployment in the plan was less effective, especially when placed on the end walls, where half of the heat absorbed by the masonry would be radiated to the outside of the house. The higher ceilings demanded by Georgian architecture introduced the possibility of thermal stratification of the air that had been largely prevented by older lower ceilings. The more expansive floor plans demanded windows on all sides to provide adequate daylighting (whale-oil lamps and spermaceti candles now provided illumination after dark), and this development, coupled with the larger double-hung windows that were becoming common, broke down the importance of southern exposure and reduced the thermal resistance of the building envelope.

Advancements in the technology of building and insulating walls and windows has advanced greatly since the 1700's, but these developments only serve to mitigate the effects of dwelling designs that to this day continue to be based on pretensions or imitations of style rather than on responses to the climate that the buildings protect their occupants from. Until recently the entire history of residential heating has been one of perfecting the source of artificial warmth to compensate for, rather than work in harmony with, the performance of the building envelope.

CHAPTER III

THE CENTRAL FIREPLACE

The most important feature of the early colonial houses was the massive central fireplace and chimney. As the sole source of warmth for the entire dwelling these were crude devices, requiring a tremendous quantity of fuel and attention, but they did combine heating, cooking and lighting in a core structure that provided a focus for all aspects of domestic life, in form anticipating by two centuries the refinements of Catherine Beecher's American Woman's Home.

The fireplaces in the first "wigwams" and one room houses were made of field stones gathered from the countryside, carefully fitted and laid up with a mixture of clay, sand and grass. For a time the chimney above the fireplace was made of logs, laid up two-by-two and packed and lined with mud or clay. This soon proved to be an entirely unsatisfactory method, for the clay and mud made an inferior mortar, especially with the rounded glacial rock that was common to New England. The clay-lined wood chimney had been satisfactory in England, where it was used over modest cooking fires, but the intense heat of the large fires made necessary by the harsh New England winters caused the mud to dry and crumble, exposing the wood to the heat of the fire. So many houses burned down in this manner that the practice of building wood chimneys was soon banned.¹

True chimneys of any size awaited the discovery of a satisfactory mortar. The first was made by grinding seashells to a powder which was then roasted. The cement thus made proved to be both heat and moisture resistant.² Undoubtedly many chimneys were built using this seashell mortar, for it was not until the mid-1600's that lime was available in the

New England colonies. Further south, in New Jersey and Virginia, lime for mortar had been available earlier, being imported from Bermuda in exchange for the output of the flourishing brick making industry.³ While brick was also available and used in New England about this time, field stone continued to be used for a great many chimneys during the eighteenth century.

With the discovery of a suitable mortar, durable fireplaces and chimneys of great proportion began to be built. A typical chimney structure the size and general appearance of which are illustrated by the ruin shown in Fig. 26, consisted of a base, the first floor fireplaces and oven, the slope or "shoulder", the smaller second floor fireplaces, a ledge or dripstone (the predecessor to flashing), and the outside shaft. Often a "smoke room" was located somewhere within the chimney structure.

The base, sometimes as large as fifteen feet square, was perhaps the most varied part of the structure. The simplest were nothing more than field stones "puddled in a mixture of clay and sand (Fig. 27) that was used instead of mortar. Slabs of rock or thick oak planks were set in at intervals of two or three feet to strengthen the base and to prevent settling.

For larger chimneys the base was often built with an arch, perhaps to save material, but also to add rigidity to the structure (Fig. 28). Some of these arches were seven or eight feet high. The space underneath the arch was often used for storage.

The first floor fireplaces (which in a one story house were of course the only ones) were huge: three or four feet deep with an opening often eight feet wide or more and five or six feet high (Fig. 29). The opening was usually spanned by a huge wood lintel, sixteen inches square,

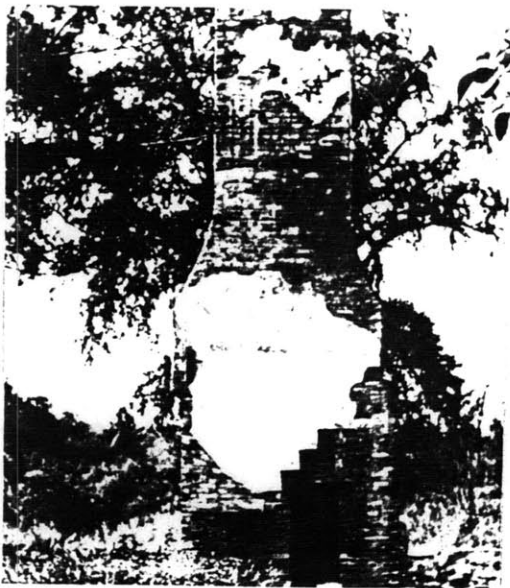


Fig. 25

The massive size and basic elements of the central chimney are clearly seen in these pictures of a ruin.

Fig. 26

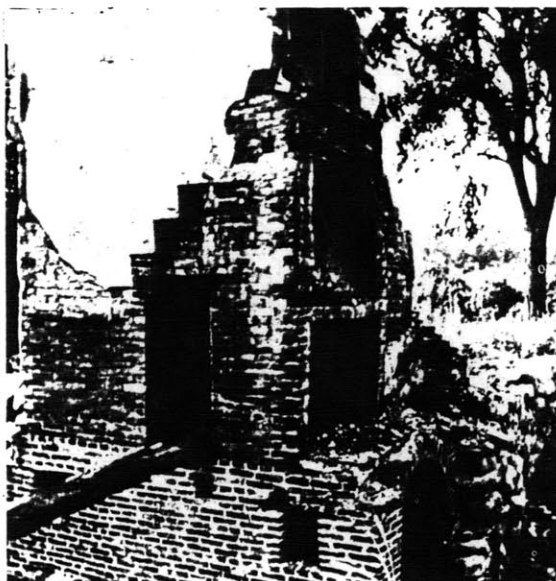


Fig. 27: The base of the chimney was often made of field stones "puddled" in a mixture of clay and sand.

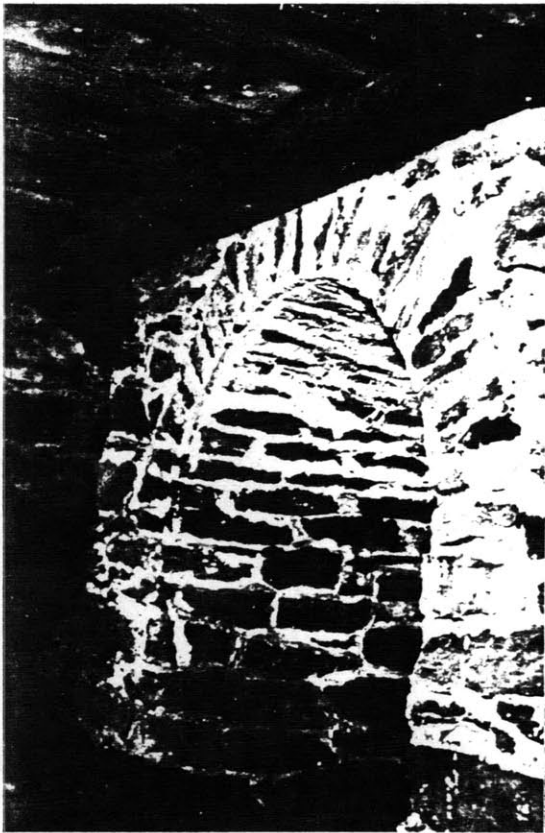


Fig. 28: An arch in the base added rigidity to the chimney. Such arches were often eight feet high.

Fig. 29: The large central fireplace, focus of the house.

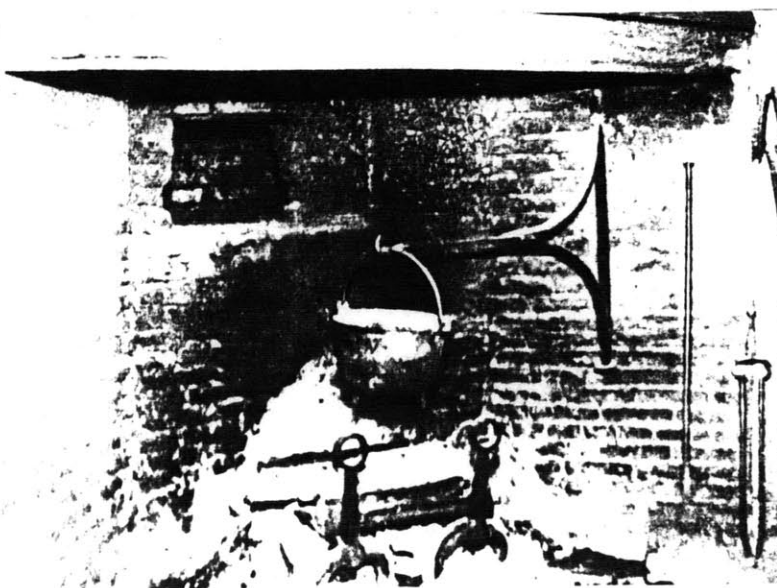


Fig. 30: The first ovens were located at the back of the fireplace.

that supported the masonry above. Being so close to the fire, it was not unheard of for the lintel to catch fire, occasionally causing the collapse of the entire chimney.⁴ Later an iron bar was used in place of the wood lintel.

The throat of the chimney was generally huge, allowing storms to beat down on the fire and an occasional bird to fly down in search of shelter. It was no wonder that as much as 90% of the heat generated by the fire went straight up the chimney.

The first fireplaces had no ovens -- all cooking was done in and over the fire. The first ovens were located at the back of the kitchen fireplace (Fig. 30) and had no draft opening. The oven was heated by building a fire in it, leaving the wooden door open a crack to create a draft. When the oven was hot enough the coals were removed, the food placed inside and the door closed. The intensely heated brick walls of the oven would hold the heat for several hours.

Since one had to step into the fireplace or reach over the fire to get to the oven it is no wonder that that location did not prove too popular and before long gave way to ovens built to one side of the fireplace opening. These at first had a beehive shape, with a round floor about thirty-inches in diameter and a domed top and usually had a flue opening that connected to the chimney, since the door opening was no longer within the fireplace. The wood doors of the oven were replaced by tin when it became available and, by the beginning of the nineteenth century, by cast iron doors on iron hinges. Often the tin or wood door was retained when the iron one was fitted, since the two doors would hold the heat better.

Above the first floor the chimney tapered to the size of the second floor fireplaces, which, being used solely for heating, were smaller and

shallower than the ones below. The taper or "shoulder" was usually enclosed by paneling to make a narrow closet.

Above the attic floor the chimney usually tapered again to the size of the outside shaft, although in many cases the shaft remained the size of the attic chimney.⁵

Many larger houses had built somewhere in the chimney structure a smoke oven or room, with a flue, which was used to smoke meat (Fig. 31). These spaces were sometimes located in the cellar; sometimes off the landing or an upstairs room. The meat was hung from hooks or poles and smoked for three days over a smoldering fire of corncobs and hickory bark.⁶

Except for baking which was done in the brick oven at the side or back of the fireplace, all cooking in the colonial house was done in the large fireplace itself. Food was cooked and water boiled in pots and kettles which were suspended over the fire by means of pot chains and trammels (Fig. 32) from a hardwood lug pole or trammel bar which spanned the width of the chimney throat opening. As might be imagined, this bar occasionally charred through, dumping the family's dinner into the fire. In 1720 the iron crane was invented. It was fastened to the side wall of the fireplace and swung out over the hearthstone. Meat was roasted on a spit, the first of which were hung vertically over the fire. Later spits were horizontal and elaborate mechanical devices were sometimes devised to turn the spit automatically. Sometime during the 1700's the tin roasting oven or "tin kitchen" (Fig. 33) was invented. This was a half cylindrical reflector oven that was placed in front of the fire.⁷ Beyond these more basic cooking tools there was a tremendous variety of specialized implements for almost every cooking need. An excellent description of these may be found in Chapter III of Mary Earle Gould's The Early American House.



Fig. 31: A smoke room built within the chimney structure.



Fig. 32: Pot chain and trammel.

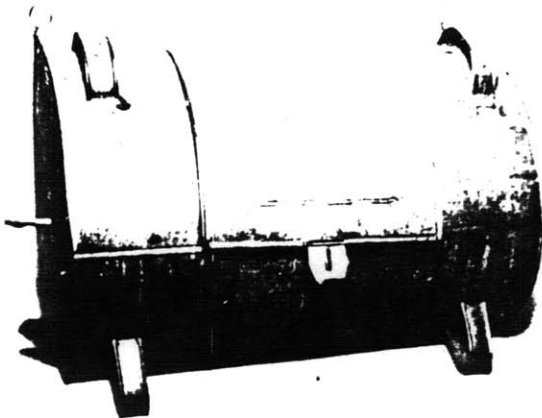


Fig. 33: "Tin kitchen"

The fire was one of the most basic essentials of life in colonial New England, and maintaining the fire was a major occupation of the lives of the settlers. Every effort was expended to keep the fire burning continuously throughout the winter, owing to the difficulty of rekindling the fire if it should die out. Fire could be made only by striking a piece of flint with iron or steel so that the resulting spark would fall into the tinderbox and ignite the tinder, a very dry inflammable substance such as a partly charred linen cloth. This task could take a half hour or longer, and often it was more convenient to walk to a neighbor's house and borrow a few hot coals.

At night when the fire was banked some of the live embers would be covered with ashes. Thus cut off from much of the oxygen, the embers would usually stay alive until morning when the fire would be rebuilt.⁸ Instead of raking the ashes over the embers some houses used a curfew (from the French "couvrefeu" "to cover the fire"), a large dome-shaped copper cover that restricted the amount of air that reached the fire.⁹

Keeping plenty of dry wood on hand was another major task. Wind-fallen or standing dead trees were preferred as they were at least partly free of sap. Wood was cut to fireplace length (in those days, about four feet), split and kept under cover whenever possible. To heat a small house, cook and provide hot water for washing dishes, clothes and selves required fifteen to twenty cords of wood a year (a cord of wood is a pile measuring 4 feet wide by 4 feet high by 8 feet long).¹⁰

The early colonial houses were certainly drafty in winter, a condition caused in no small way by the voracious demand of the roaring fire for air. Cold air rushed in through the slightest crack around the doors and windows. These conditions had great influence on the type of furniture that was found around the fireplace. Settles, high-backed

benches or chairs, were the most popular, their high solid backs shielding their occupants from the chilling drafts (Fig. 34). A hutch table that opened into a settle was another popular and useful piece of furniture (Fig. 35).¹¹ A wooden crane was often hung at one side of the fireplace to hold a blanket that acted as an additional screen from the cold.

Drafts were not the only discomfort, for the house was generally cold, especially if one got any distance at all from the radiated warmth of the fire. Underfoot there was usually nothing but bare boards to keep out the cold from the cellar or bare earth below. Rugs were too precious to be trod upon and were kept on the table where they belonged.¹² The diaries of Cotton Mather and Judge Samuel Sewall report that ink froze in the inkstands and that sap oozing from the burning logs froze before it caught fire.¹³ Water would freeze in a basin just fifteen feet from the fire.¹⁴ To keep warm, everyone kept working. Whatever work could be brought in front of the fire, was. For the women this was often spinning, weaving and sewing, in addition, of course, to cooking; for the men, wood-carving and tool making were frequent pastimes.

Another way to keep warm was to drink, and everyone did: the minister, grandmother, even six-year-old children. The widespread, though moderate, drinking was however largely the result of the fact that sanitary conditions often left the water unfit to drink.¹⁵

A number of devices were used to provide warmth away from the fireplace. Most of these simply provided a way of making the fire portable by means of a suitable container. Perhaps the most common of these was the footwarmer, an iron box which could be filled with coals and carried about the house (Fig. 36). The traveling foot warmer (Fig. 37) was covered with carpet and taken on journeys. The bedwarmer was mounted on a pole and passed between the sheets before retiring to warm them.¹⁶

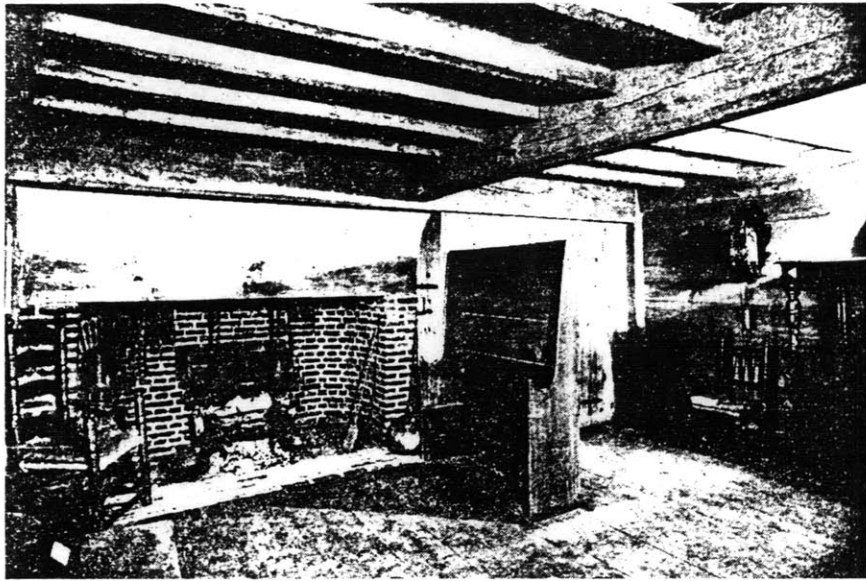


Fig. 34: The high-backed settle protected its occupants from chilling drafts.

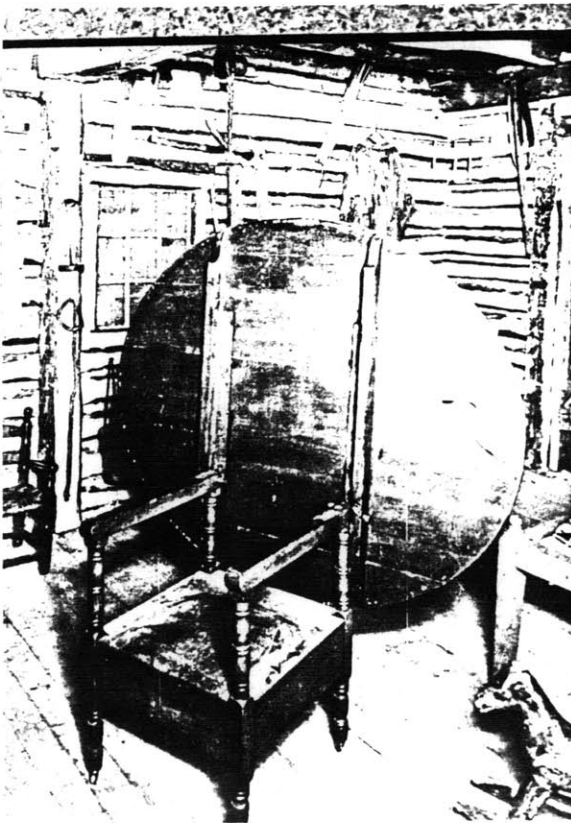


Fig. 35: A hutch table that opens into a settle.

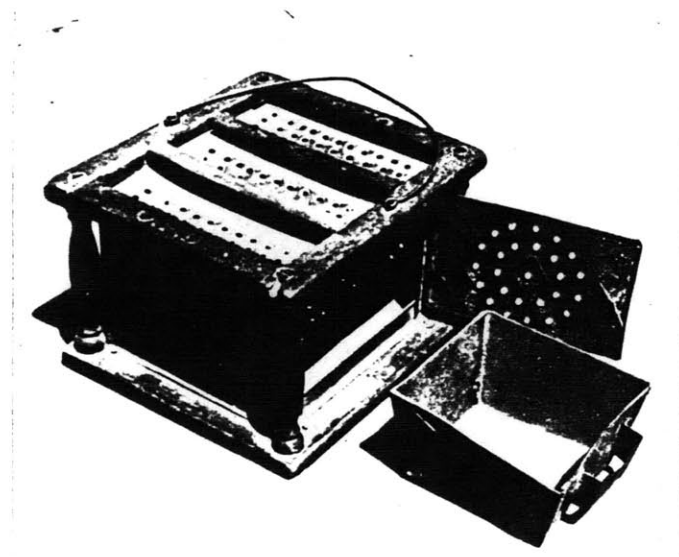


Fig. 36: Footwarmer.

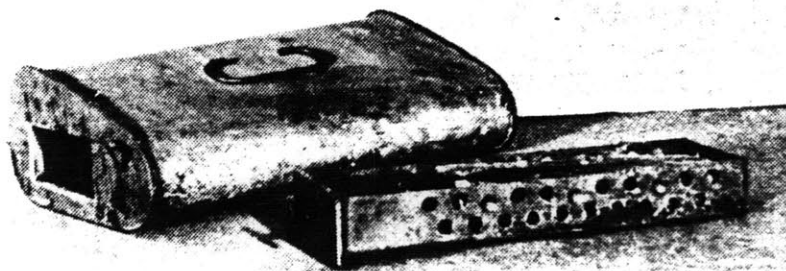


Fig. 37: Traveling footwarmer.

CHAPTER IV

CHANGES IN THE FIREPLACE

Unlike their ancestors in Britain, the first settlers in New England literally had all the wood they could burn, and burn it they did. Though the gathering and splitting of firewood was an arduous and time-consuming task, it was apparently accepted as necessary, for there do not appear to have been any significant early efforts to cut wood consumption. Probably no such effort was deemed necessary. The country was so well forested in the early years that it was seldom necessary for townsfolk to venture far for wood; an ample supply could be cut nearby and brought into town.

The only town threatened with a fuel shortage in this period was Boston. Though the shores of Massachusetts Bay were well wooded, no timber grew on the peninsula itself. During the winter of 1637 the scarcity became so acute that for a time the inhabitants considered abandoning the settlement. To relieve the shortage wood was brought by sled from the mainland in winter, and by boat from the harbor islands in the summer. Gradually roads were opened, allowing wood to be brought from the Muddy River and Roxbury, but the poor suffered each year from the scarcity and high cost of wood.¹

Despite the problems of Boston, which were really the result of the town's peculiar geography, wood was in plentiful supply elsewhere, and remained the universal fuel throughout the seventeenth century and the first third of the eighteenth. However, America's wood consumption was so great that just one hundred years after the first settlements were established the colonists were faced, though they probably did not realize it, with the possibility of a fuel situation similar to what their

ancestors had gone through in England. As towns grew in size and population and forests receded the problem of procuring adequate supplies of firewood became increasingly acute. Wood vendors seem to have been an unscrupulous lot, often selling wood of short measure. In Newport, where the forests were so rapidly denuded that by 1713 fuel was being brought by boat, a fine of twenty shillings a cord was placed on all wood that failed to meet the official four foot measure. Well before 1720, most towns had found it necessary to regulate the sale of firewood in some way.²

By 1720 the forests had receded so far that most towns found it necessary to transport fuel from distant points at ever-increasing cost. Fuel prices rose steadily, causing real problems for the poor, who could not afford to lay in an advance supply during the summer when prices were lower. The situation was particularly acute in Boston. Plans for improving the fuel supply were repeatedly postponed until the bitter winter of 1740-41 found the community totally unprepared. The town was forced by necessity to spend £ 700 for wood for the poor and to provide a ware-³house where wood given for charity might be stored and dispensed.

A similarly acute shortage occurred in Newport, where a writer in the Rhode Island Gazette put forth perhaps the first American proposal for conservation: "When I consider how much the Price of Wood for Firing has advanced in this town for thirty Years past, it puts me to some Apprehensions for Posterity." He proposed a reforestation law requiring every farmer to plant a certain number of trees, and an act to prevent waste in the cutting and selling of firewood.⁴

As was pointed out in Chapter III, during this period new fireplaces were often built smaller than was the earlier practice, and it was not at all unusual to find fireplaces being altered, generally by being made smaller. The fact that wood was less readily available seems to be one

of the principle reasons why. The fireplace in the Simon Willard house in Harvard, Mass., originally ten feet long, is said to have been made smaller seven different times.⁵

A good example, though from a slightly later period, of the nature of these modifications can be seen in the Golden Ball Tavern in Weston, Mass. In that building the original kitchen fireplace was substantially rebuilt in 1805 after a new kitchen ell was added (the added fireplace is preserved intact). The hearth opening was reduced by the construction of new side and rear walls, and a front-mounted bake oven was added to the right of the fireplace, within the original opening (Figs. 38 and 39). Later in the nineteenth century the entire fireplace opening was bricked up and a free-standing wood-burning range installed with the flue opening cut through the wood paneling above. Still later a coal-burning range was installed and a new flue cut into the bricked-up fireplace front.

In a rear chamber of the Golden Ball is a rather curious and by no means typical modification (Fig. 40) in which a brick false front has been built in the original deep fireplace in the basic proportions and shape of a "Franklin stove".⁶

While these early fireplace modifications may have been merely intuitive responses to the increasing scarcity of wood, it is more likely that they were guided by the growing scientific understanding of the nature of heat (which had generally been considered to be a particulate substance) and the functioning of fireplaces and chimneys. At the start of the eighteenth century an avid interest in the problem of heating arose, and it became one of the major topics in communication between men of learning. Throughout the century men of science were advising that fireplaces operated better when made smaller, since smaller

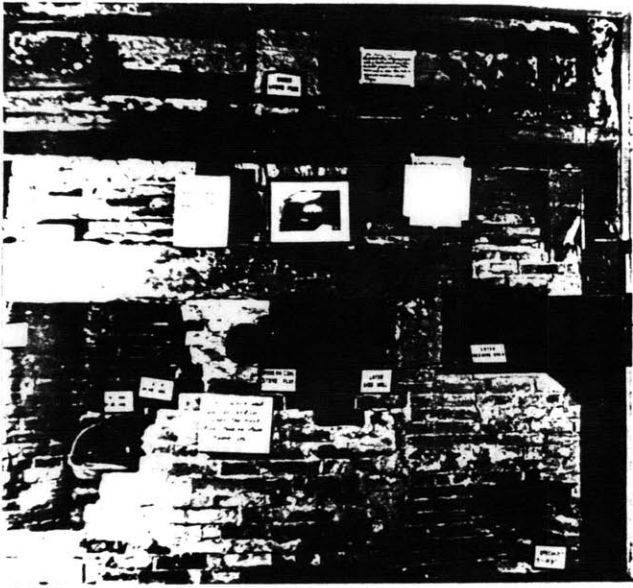
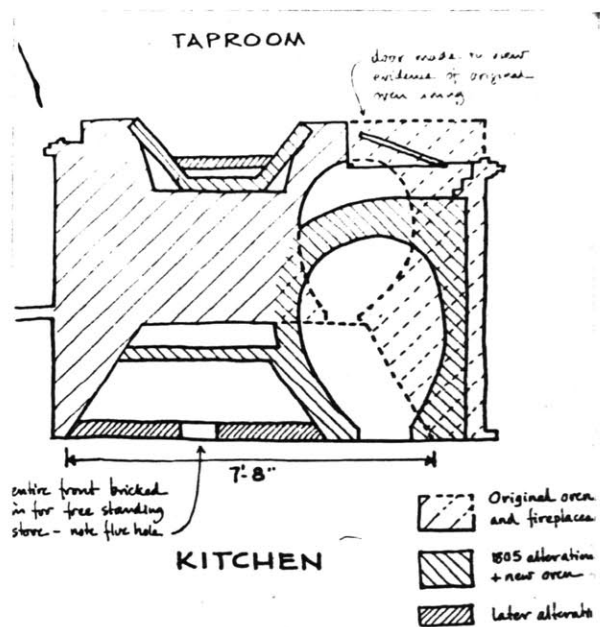


Fig. 38: Fireplace in the Golden Ball Tavern, Weston, Mass., showing the successive modifications that were made to it.



GOLDEN BALL TAVERN - WESTON, MASSACHUSETTS

Fig. 39: Diagram of modifications to kitchen fireplace at the Golden Ball Tavern.

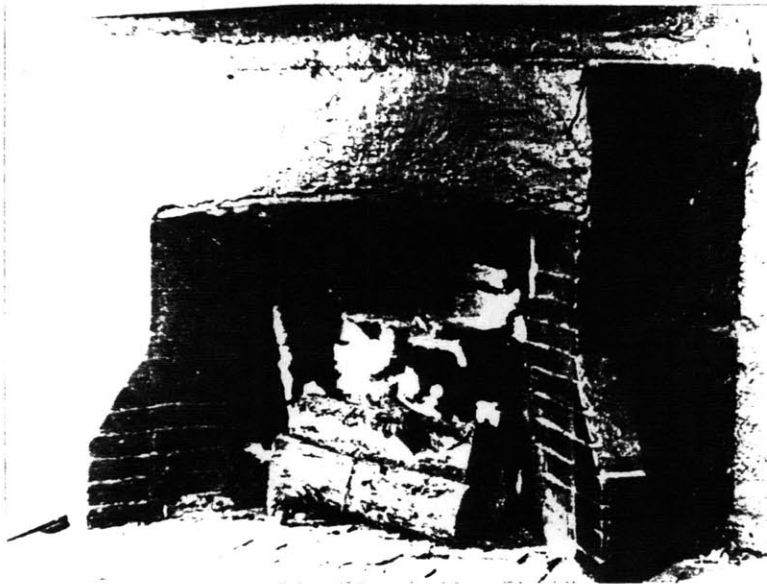


Fig. 40: A curious fireplace modification in the form of a "Franklin stove."

openings proved to cause a greater draft, making a hotter fire and allowing less heat to escape up the chimney.⁷

The first efforts to bring some level of sophistication to fireplace design came in 1715, when a scientist named Jean T. DesAguliers, supplementing the work of a Frenchman, Nicolas Gauger, with the principle of "rarified air" (the fact that heated air rises),⁸ published what was perhaps the first English language book on heating. Two inventors who were familiar with the work of DesAguliers and Gauger and who made significant contributions to the art of fireplace design were Benjamin Franklin and Benjamin Thompson, the latter more commonly known as Count Rumford.

Franklin and Rumford were both disturbed by the inadequacy of the fireplaces of their time, which consumed a tremendous amount of fuel for the amount of heat they put out; induced uncomfortable drafts in the house; and whose chimneys were apt to spew smoke and soot, the result of incomplete combustion. Furthermore, there was no means of regulating the draft or rate of burning.

In the field of heating Franklin is of course better known for his "Franklin stove" (discussed in the following chapter), but he had some significant observations about conventional fireplaces as well. In a letter to a friend in Boston, written while he was in England in 1758, Franklin suggested the concept of a movable iron plate in the chimney throat to adjust the draft of the fireplace according to need; in other words, a damper. His most famous treatise on fireplaces, "Observations on smoky chimneys, their causes and cures," was written as a letter aboard ship in 1785 and published in 1793. In it he described experiments which showed that "no form of the funnel of a chimney has any share in its operation or effect respecting smoke, except its height."

He argued that the size of a fireplace opening ought to be in proportion to the height of its chimney and again suggested the use of dampers in chimneys to regulate the draft.⁹

BENJAMIN THOMPSON, COUNT RUMFORD

The most notable authority on open fireplaces in the late 1700's was Count Rumford. Born Benjamin Thompson at Woburn, Mass., in 1753, he studied medicine briefly and taught himself astronomy and mathematics. At the age of nineteen he was appointed a schoolteacher in Rumford, New Hampshire (now Concord), where he soon married a rich and well-connected widow fourteen years his senior. This even in no way hindered his ambition, for he quickly impressed the Royal Governor, who became his patron. As the American Revolution approached, Thompson was, justly, branded a Loyalist, and eventually forced to flee to London, where he conducted his most famous experiments with heat. In addition to being a skilled reformer and administrator Thompson was a cautious, thorough, first-rate scientist. Among his many inventions were a shadow photometer, a variety of advanced cooking stoves, a roaster and pressure cooker and the drip coffeemaker. In 1792, while in Bavaria, he was named a Count of the Holy Roman Empire, taking for his title the name of the village where he had his first success. Unfortunately, among Rumford's many talents was that of making enemies, and he was eventually forced to leave England to spend his last years in Paris experimenting with heat under the patronage of Napoleon.¹⁰

Rumford was a strong advocate of the narrow-throated flue, arguing that a four inch width was proper regardless of the size of the fireplace (since the length of the throat would naturally be longer in a larger fireplace), and that a better draft could be obtained by keeping the throat close to the fire. He recognized that fireplaces heat primarily by

radiation and suggested that the sidewalls or "covings" of the fireplace be set at a 135° angle from the back so as to radiate the greatest amount of heat into the room. In his directions for the modification of fireplaces he advised that the fireplace have a depth of 13". This gave an optimum opening width of 39". The recommended height of the opening was three feet. Rumford's modifications were readily accomplished by building new fireplace walls within the old opening; the added wall of bricks at the rear would give the proper depth, reduce the smoke opening to 4 inches and create a smoke shelf in the flue. To provide access for chimney sweeps Rumford suggested that a few bricks at the top of the back be left unmortared so that they could be removed.¹¹

In direct opposition to Franklin, Rumford deplored the use of metals in fireplaces as having none of the heat retaining qualities of firebrick or common brick, advising that the brick be plastered and whitewashed to increase their reflectivity.

Rumford personally applied his modifications to over 500 fireplaces with near universal success and instructed many other workmen in the proper procedures. The results, he noted, were impressive: a fuel saving of half to two-thirds in most cases against a trifling expense for bricks and mortar. Aside from the fuel saving he noted as benefits that the smoking fireplace was eliminated, rooms were more evenly warmed and kept at the desired temperature, and drafts from windows and doors were eliminated.¹²

Rumford's works were first published in England in 1792 and in this country six years later. Historians differ on the impact of his work on the evolution of fireplace design. Edgerton states that Rumford's ideas got immediate and nearly universal acceptance and were used in fireplace construction until such fireplaces were no longer used for heating. Asher Benjamin advocated the incorporation of Rumford's ideas in his highly influential American Builder's Companion, first published in Boston

in 1806.¹³ On the other hand, Rowsome claims that Rumford's proportions did not spread immediately and were never absorbed into the mainstream of fireplace design, though a few venturesome people built them (and some still do). He cites three possible reasons for the apparent lack of popularity of Rumford's ideas: they called for a little extra masonry skill; they appeared at a time when iron stoves were beginning to take over the space-heating function of fireplaces; and they looked unconventional.¹⁴

With regard to wood-burning fireplaces, Rowsome's assessment is probably more nearly correct. The proportions that Rumford espoused are virtually forgotten today, and only rarely in surviving 19th century fireplaces does one find all of Rumford's basic principles in use. Frequently the mouth of the fireplace will be about right, but the shallow depth and 135° covings so essential to Rumford's design are seldom found. The trend to smaller fireplaces was more likely a response to the general scientific consensus that smaller fireplaces worked more efficiently than to the specific recommendations of Rumford, which came along after the trend was underway.

Furthermore, among the more educated and wealthy classes who were more likely to have been exposed to Rumford's ideas, changes in the manner of heating the house were taking place. Iron stoves along the designs of Franklin and others were becoming increasingly popular with those who could afford them. In the larger towns such as Boston, the growing scarcity of firewood was causing a shift to coal, and fireplaces were being built or modified to accept the new fuel. It was probably in this area that Rumford's ideas had the greatest influence, for most of his work with fireplaces was done in England, where coal burning fireplaces were common, and a substantial portion of his work deals with the proper installation of coal grates.

CHAPTER V

THE WOOD BURNING STOVE

Though the dominant figure in the history of wood stoves in America is unquestionably Ben Franklin, stoves were known in Boston and elsewhere during the seventeenth century, well before Franklin's time. Most of these were probably of the "Holland" type of which Franklin spoke in the pamphlet promoting his stove. The "Holland" stove was a closed type, basically a box formed of six iron plates and vented by a separate flue or stove pipe that served to radiate additional heat into the room. The heat could radiate from all sides of these stoves, but their closed nature endowed them with certain difficulties, as Franklin noted:

"... People not seeing the Fire are apt to forget supplying it with Fuel 'til 'tis almost out, Then growing cold a great deal of Wood is put in, which soon makes it too hot. The change of air is not carried on quite enough, so that if any Smoke or ill Smell happens in the room, 'tis a long time before 'tis discharged."¹

Franklin also reported on a stove that was popular among German immigrants in Pennsylvania. This stove (Figs. 41 & 42) was made up of five cast iron plates, whose wonderfully complex designs often depicted Biblical scenes, giving rise to the name "the Bible in Iron". The open sixth side was placed against the back side of the kitchen fireplace (in the adjoining room). Wood was fed to the stove and smoke ventilated through openings in the fireplace wall. Franklin thought even less of this stove than he did of the "Holland" stove, for with the five plate or "jamb" stove, as it was known, one had no way of checking on or attending to the fire from the room in which the stove was placed.

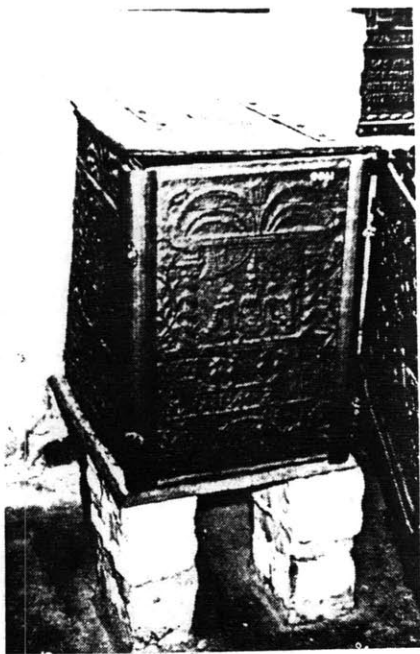


Fig. 41: Five plate
"German" stove, Berks
County, Pa.

Fig. 42: Installation of the 5 plate stove

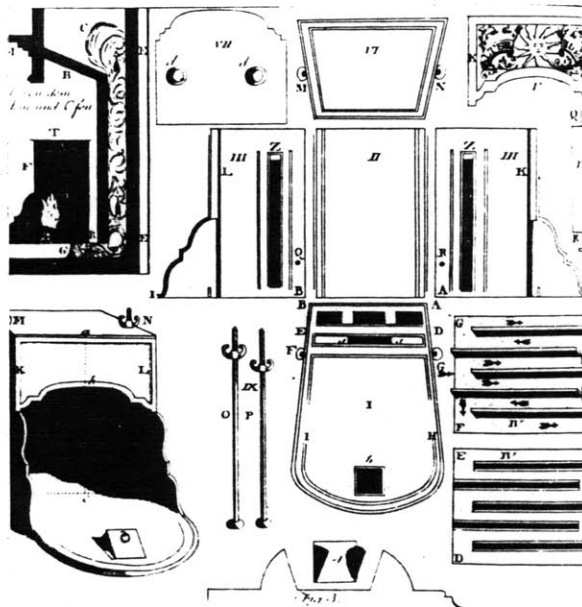
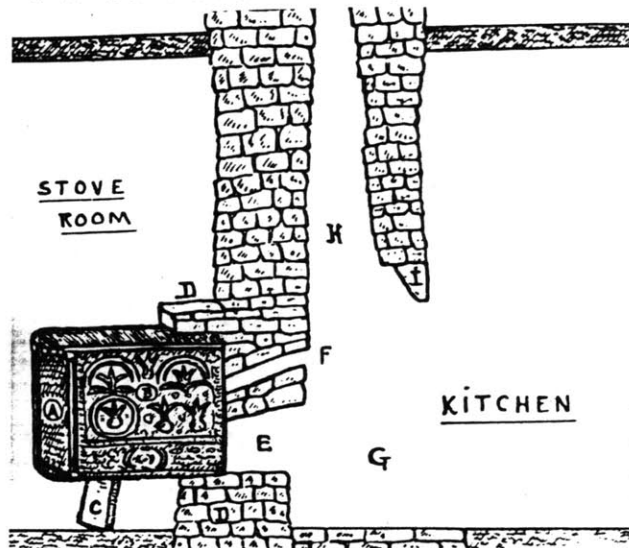


Fig. 43: Diagram of the components
of Benjamin Franklin's original
"Pennsylvania Fireplace," 1744.

Franklin's own stove design was an effort to build a stove or fireplace that would be acceptable to the traditional English preference for the open fire that had followed the colonists to the new world, and that at the same time would incorporate the knowledge about chimney drafts and fireplace efficiency.

In its operation the Franklin design was not totally new, borrowing heavily from the work of DesAguliers and Gauger. DesAguliers had offered several designs for iron or brass plated fireplaces, open in the front, with enclosed air cavities. These received air from holes bored through the hearth masonry below. As air passed by the heated metal plates of the back of the fireplace it was warmed and, rising, was expelled into the room through outlets at the top. In its construction and operation this fireplace was very similar to the modern eatilator. Though a few appeared in England in the early eighteenth century, its complex and unusual design was probably too far ahead of its time and never caught on.²

Franklin produced his first cast iron stove in 1739-40 and in 1744 published his famous pamphlet to promote the sale of the new stove. The stove was open in front, with a wood fire resting on andirons in the normal, English-approved manner. Its structure and operation were anything but simple, however, as illustrated in Fig. 43 and Edgerton's description:

"The stove was set in place so that its bulk was within the room itself with the fireplace opening bricked up tightly behind its back plate. The smoke escaped through a two or three inch wide trench dug in the bottom of the old fireplace hearth, linking a hole in the bottom iron plate to the chimney opening behind the back plate of the stove. The smoke and heat from the fire rose and passed over a baffled air-box within the stove. This air-box was tightly constructed of two iron plates with another opening in the bottom through which it received air from the outside. The air in the air-box was "rarefied" by the heat passing up, over and down its exposed surfaces. This heated

air would then be expelled into the room from two holes on the upper side plates of the stove, being forced out by the colder air pressing in through the small opening on the bottom. The small door on the bottom plate could be utilized to take advantage of the draft in the little trench beneath in order to blow up the fire in the morning. The insignia on the front plate was Franklin's comment on the mass₃ production of his stoves: ALTER IDEM - 'another like me.'"³

To make his stove as widely available as possible, Franklin took out no patent on it and gave the design to several people, including his friend Robert Grace, who took on agents in several cities and shipped the stoves all over the colonies. However, the high cost of transporting the stove pushed its price to several times the \$20 that it sold for in Philadelphia, and few were sold outside of that city.

In addition to high price, Franklin's "Pennsylvania Fireplace" suffered from its complicated operation, which was really too much for unskilled hands and unsuited for many existing chimneys. Modifications to the design soon appeared which, while simpler, incorporated fewer of the significant advances of the original design. A stove cast at Berkshire furnace, Berks County, Pa., around 1785 provides a good illustration of the nature of these modifications (Fig. 44). The unconventional smoke egress, which apparently required a greater draft than most chimneys were capable of providing, was moved from the bottom to the top of the back plate. The baffled air chamber, probably the most important feature of Franklin's design, was eliminated in favor of an interior back plate that slanted forward slightly to reflect more heat back into the room and to form a smoke shelf within the stove. These stoves were rarely installed free of the fireplace, as Franklin had advised. Instead they were usually set about halfway into the old fireplace opening, which was then bricked up tightly around the stove. Since no air passed under the stove, Franklin's bellows device was eliminated.⁴

A later version of the modified Franklin stove that appeared first

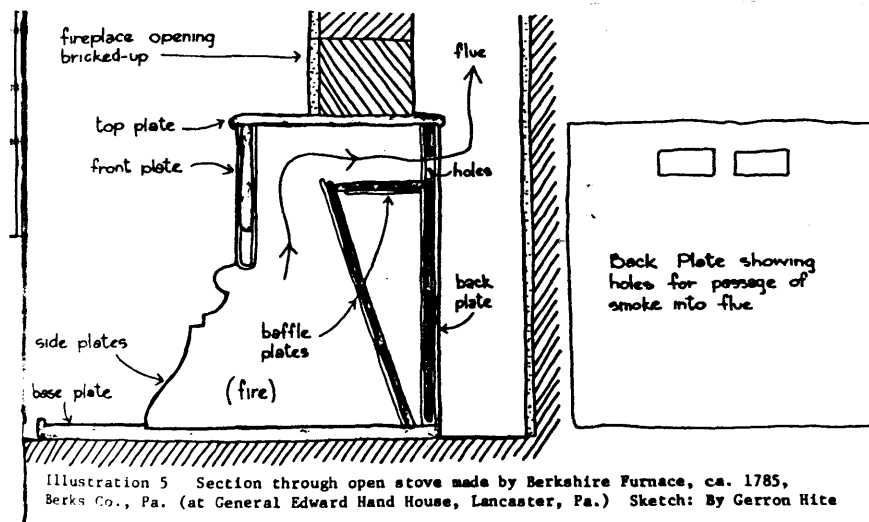


Fig. 44.

in the early 1780's and enjoyed great popularity was the "Rittenhouse" stove (Figs. 45 - 47). In this the side plates were cast in a "Z" shape, allowing the elimination of the large one-piece back plate. The three smaller plates that formed the back of the stove defined a smoke shelf and built-in flue. In this respect the Rittenhouse was functionally similar to the Berkshire stove but, since it used less material, was lighter and cheaper to build.⁵

Open stoves with curved front and side plates (Fig. 48) became increasingly popular in the early nineteenth century. This form was made possible by the development of "flask casting," a method of casting the plates in a two-part mold as opposed to open sand casting which had limited the pouring of iron to flat shapes.⁶

That Franklin's original design never achieved substantial popularity is evidenced by the fact that, though it was widely published both here and abroad, there is no known example of an eighteenth century stove operating on the basis of his original idea.⁷ This lack of popularity can be attributed to three factors: first, the complexity of the design; second, the extent of the modifications to the fireplace that were necessary; and third, the high cost. It further appears that interest in open stoves lagged in the decades before the Revolution and that all types of such stoves were rare during that period. After the war interest apparently revived, but entirely in the simpler modified versions that in operation bore little resemblance to Franklin's invention, being in fact little more than cast iron fireplaces. Their superficial resemblance to the original, though, caused these open stoves to be referred to more and more as "Franklin Stoves," a name that they have retained to this day.

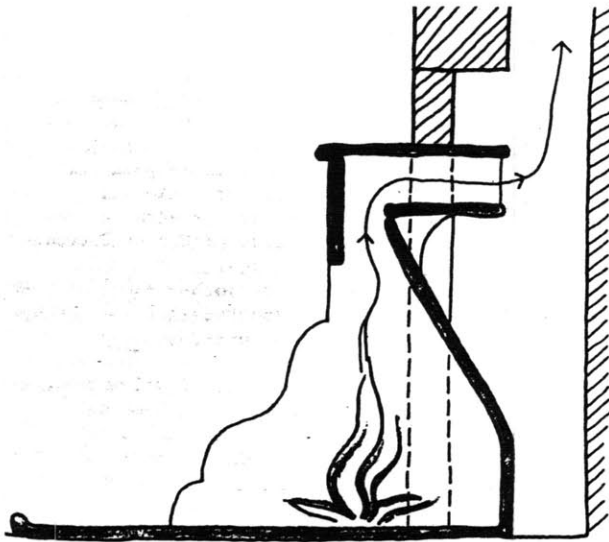
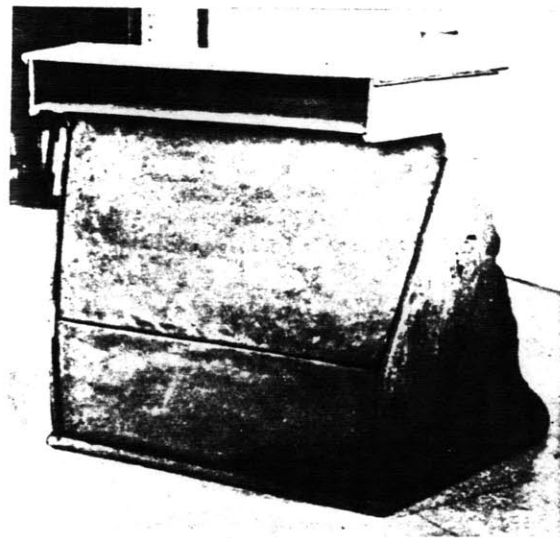
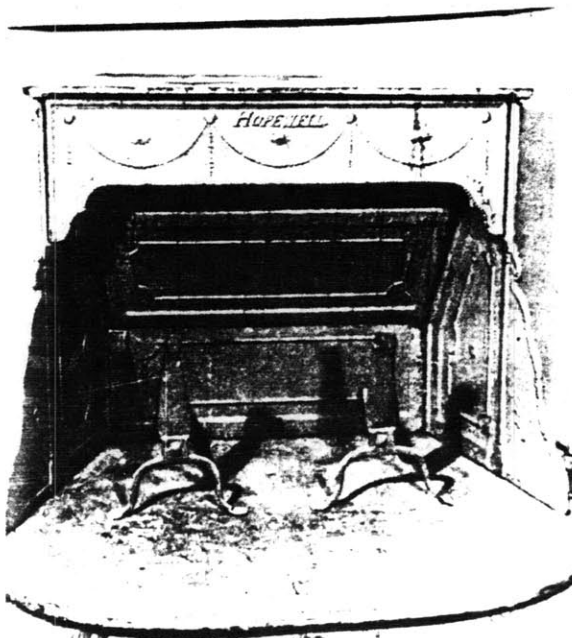


Fig. 45: Diagram of the "Rittenhouse" stove showing its installation in the fireplace and means of smoke egress.



Figs. 46 & 47: "Rittenhouse" type stove. Franklin's design had been simplified to little more than an iron fireplace.

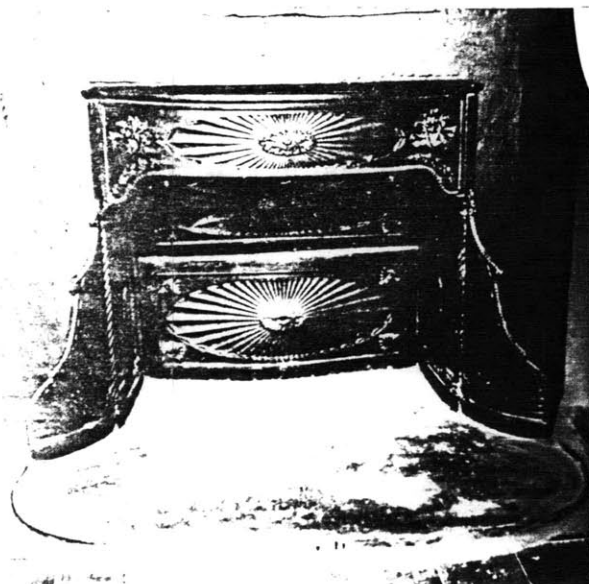


Fig. 48: Open stoves with curved side and front plates were made possible by the development of a process known as "flask casting."

FIREBACKS AND FIREFRAMES

Small iron "firebacks" were popular in the 16th and 17th centuries both in Europe and in colonial America. These were flat decorated plates of cast iron, usually measuring between two and three feet in height and width and often resembling a gravestone in appearance. They were simply leaned against the back of the fireplace or attached to it with iron anchors. Their primary purpose appears to have been decorative, for though their blackened surface would absorb more heat which could then be reradiated to the room, they would not reflect radiated heat from the fire as well as the lighter brick fireplace lining that was often plastered or whitewashed. By the late 1700's the small fireback had been replaced with large slabs of cast iron which covered the entire back and sides of the fireplace.

A similar development was the fireframe, which was essentially an open stove without the back plate, which was made of brickwork as in a conventional fireplace. The fireframe combined the advantages of the open iron stove and the masonry fireplace and was lighter and cheaper to buy and ship than a complete iron stove. Though somewhat popular around the end of the eighteenth century it seems to have been a local affection that did not spread beyond New England.⁸

CLOSED OR "CLOSE" STOVES

Paralleling the development of the open or "Franklin" stove was the evolution of the closed or "close" stove, as they were called. The first six plate stoves to become popular were really just less picturesque versions of the old decorated Holland stove that had been used earlier in Boston. A fuel door was located on the front plate and the bottom plate was often extended to the front to form an ash catcher. As with most stoves of all types during this period, the six

plate was held together with stove rods that pulled the top and bottom plates together. Six plate stoves were fairly common from the 1760's onward, especially in meeting halls, schools and churches, and remained popular for a long time, even after the appearance of its more efficient descendant, the ten plate stove.⁹

Ten plate stoves and their derivatives became more popular than their six plate ancestors and rivaled the open stove in widespread use. They first appeared in this country around 1765 and were manufactured and used well into the nineteenth century. Of European origin, these stoves were probably the grandfather of all cooking ranges. Basically they were a larger version of the six plate stove, the four additional plates forming an "oven" within the stove, access to which was gained through hinged doors on either side of the stove. With its stove pipe flue connection then ten plate could be placed anywhere within the room. The added radiation of the additional oven plates made it an economical source of heat, and it was also well known as a baking stove (Fig. 49).

After the revolution variations of the ten plate stove appeared, having seven, eight or nine plates. Of particular significance is the construction of the nine plate stove illustrated in Fig. 50. In this stove the front plate of the oven compartment is eliminated and the top and bottom plates of the oven are extended to the front plate of the stove itself. With the placement of the smoke outlet to the stove pipe at the front, this stove forced the hot gases to travel a longer distance before leaving the stove, thus increasing the amount of heat that would be given up to the room instead of passed up the chimney. In this respect the 9-plate stove anticipates the type of advances that would be seen in boiler design a century later. Further, it is ironic that it is here, in a closed stove, that we find the practical application of the innovative principles of Franklin's open fireplace. If one were

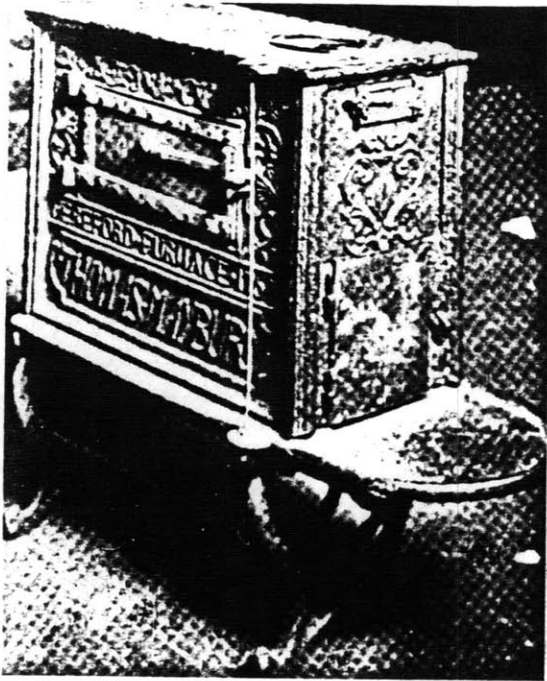


Fig. 49: ten plate stove.

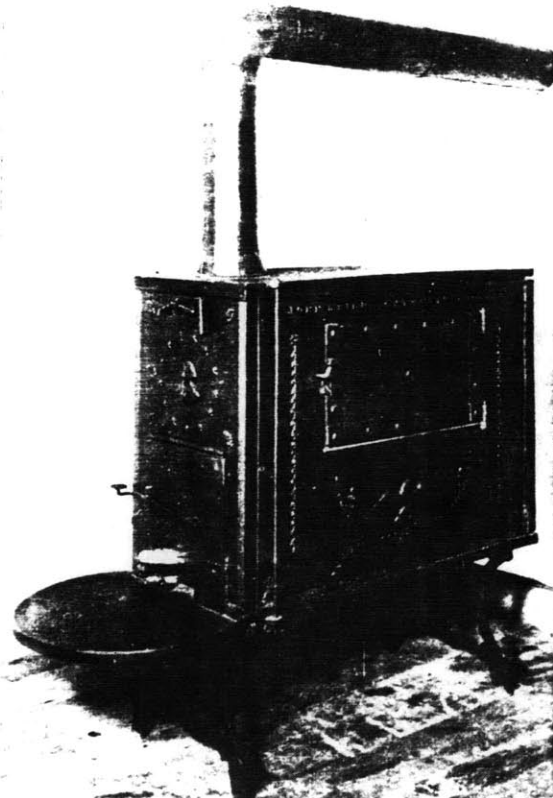


Fig. 50: Nine plate stove.

to open both of the side doors of the oven compartment on one of these stoves slightly, what one would have is essentially the same type of air warming chamber that Franklin had used in his design.

Whether open or closed, stoves of the late 1700's were not without their common problems. As in England, many people felt that air warmed by heat radiated from iron plates was "noxious" or "insalubrious" and caused illness. This was due to the burning of dust that fell on the surfaces of the stoves and to their generally overheated condition. To avoid these problems several people invented stoves made of other materials. A Charles Wilson Peale invented in 1796 a brick stove that probably worked much like the conventional open type. Such brick stoves patterned after the open Franklin type must have been barely distinguishable from the normal masonry fireplace. Stoves made of soapstone, a soft talc in rock form that has very good heat retentive qualities, also saw some use around the same time.¹⁰

A more serious obstacle to the widespread use of stoves at the turn of the century was their cost. Franklin stoves typically cost about \$20, ten plate stoves nearly twice as much, at a time when the average laborer made \$1 a day or less. And the cost of a stove would increase dramatically above those figures if it had to be shipped any distance.¹¹ As a result stoves were generally used only by the more well-to-do classes, and homes of poorer people were generally heated by open fireplaces well into the nineteenth century. Still, stoves became increasingly common. By the 1790's nearly every public building in Philadelphia that could afford it was heated by stoves, even churches, which traditionally had not been heated at all. Among the upper classes open and ten plate stoves were the most common. Most middle class families could afford but one or two stoves. Because most stoves were not considered particularly attractive they were usually relegated to the back parlors and family rooms where they would be less seen and most enjoyed.

Stove making after the revolution passed from its essentially medieval character as the nature of heat and its practical application became the objects of scientific curiosity among the sophisticates in the seaboard cities. The theory of house heating became, in the last decade of the eighteenth century, actually one of those erudite subjects upon which every gentleman was expected to be knowledgeable and conversational. The interest in heating improvement and the wide use of stoves in post-revolutionary America was due largely to the publicity given it by Franklin and by the American Philosophical Society of Philadelphia. But by the 1790's, for these men, the stove had reached the point of becoming a scientific "tour de force". Further ideas, though interesting and scientifically feasible, were impractical to the less skilled public and none found as wide acceptance as those already in use. "Smoke eating" stoves which burned their own smoke (fuel combustion in most stoves was rarely complete) and vented out the bottom were highly developed and saw some application in public buildings, but they never saw widespread use due to their complexity and the growing interest in the developing new ideas for central heating which had far greater advantages.¹²

Still, stove development did not come to a standstill. The advantages of stoves were widely recognized and their use became more and more widespread in the first half of the nineteenth century, when experiments with central heating were limited to the wealthy who could afford to take a chance on something essentially new, untested, and expensive.

An improvement over the "Franklin stove" was invented in 1816 by a Poughkeepsie man named Wilson. The "Wilson Foolscap Franklin Stove" (Fig. 51) had a hollow copper cone mounted above the stove itself; this was heated by the escaping flue gases and radiated additional heat to the room. This device was in many respects an ancestor to the

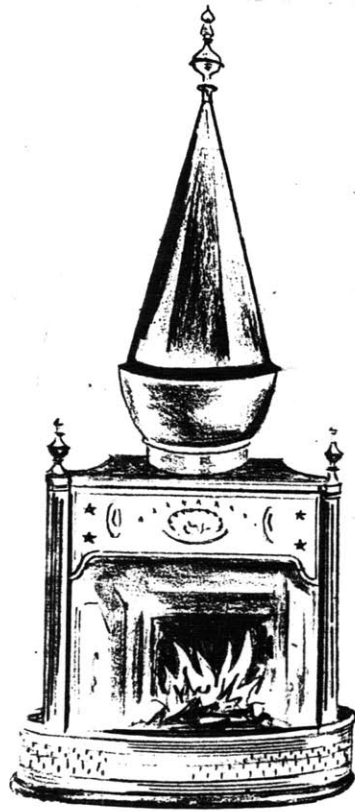


Fig. 51: "Wilson Foolschap Franklin Stove," 1816.

"radiator" mounted above the hot air furnace at the end of the century (see Chapter VIII).

By the 1840's parlor stoves were being turned out in hundreds of imaginative and in some cases beautiful designs. Later came the so-called "hot blast" airtight, drum-shaped stoves and the "baseburners," some of which were elaborately decorated with nickel plated trim. The baseburner burned coal instead of wood and made full use of radiation and convection to spread heat over a wide area. Their form survived well into the era of central heating as the heart of the typical hot air furnace.

As house construction became lighter with the introduction of balloon-frame techniques after 1840, the need to deploy the heat source directly in the interior space became greater. The iron parlor stove made it possible to bring the heat source as far into the room as one cared to run the horizontal flue pipe to the chimney. Generally these stoves were put up in the fall and taken down again in the spring when they were no longer needed for heating.¹³

CHAPTER VI

COAL GRATES AND THE COMING OF COAL

The soaring price of firewood in Boston led to some early explorations into the use of coal. In 1706 Sewall advocated the capture of Nova Scotia to procure a supply of "coals," and in 1718 the town chose a committee to investigate the importation of coal. Regular shipments of British coal began to arrive the following year, as several of the more prosperous residents found the new fuel superior to wood (needless to say, coal shipped such long distances was not cheap).¹ After 1730 the use of imported coal by well-to-do Bostonians became more general.² By 1763 coal was being mined in Hanover and Chesterfield Counties, Virginia, for shipment to New York, Newport and the Boston area.³ As coal became more readily available, coal grates in fireplaces appeared more frequently in the better dwellings in Boston and the other major towns. However, two factors prevented coal grates from ever achieving widespread acceptance in this country. These were the technical problems associated with burning coal in open grates and the high cost of the limited quantities of imported or domestic coal that were available early in the 19th century.

A coal grate (Fig. 52) is simply a device for holding lumps of coal in a fireplace so that they will burn properly. Its function is somewhat analogous to that of andirons in a wood-burning fireplace. Coal, being denser than wood, requires a more intense heat to reach ignition; to concentrate the heat the lumps of coal must be held together in a compact, hot fire. In its simplest form the grate is nothing more than a screen or basket which forms its bottom and two or three iron bars that form its sides and keep the mound of coals together. Most of the air necessary to support combustion is supplied from below.

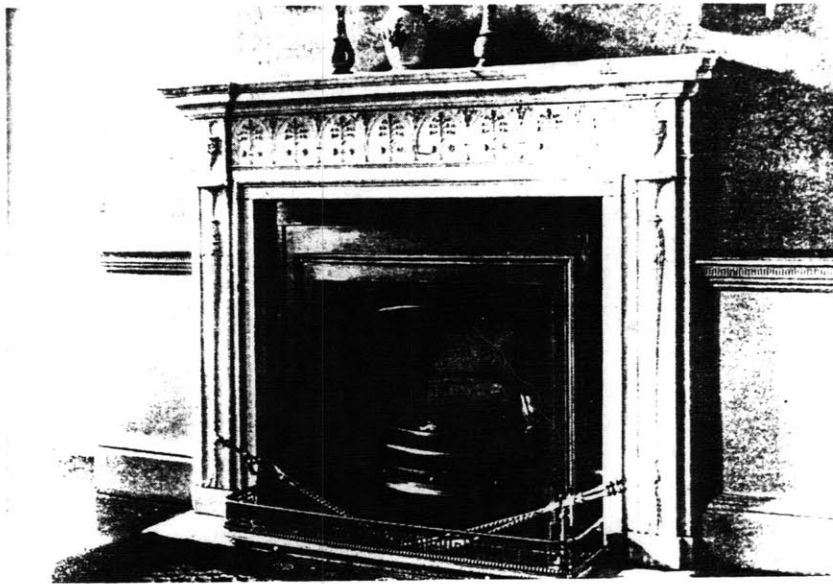


Fig. 52: Fireplace equipped with a coal grate.

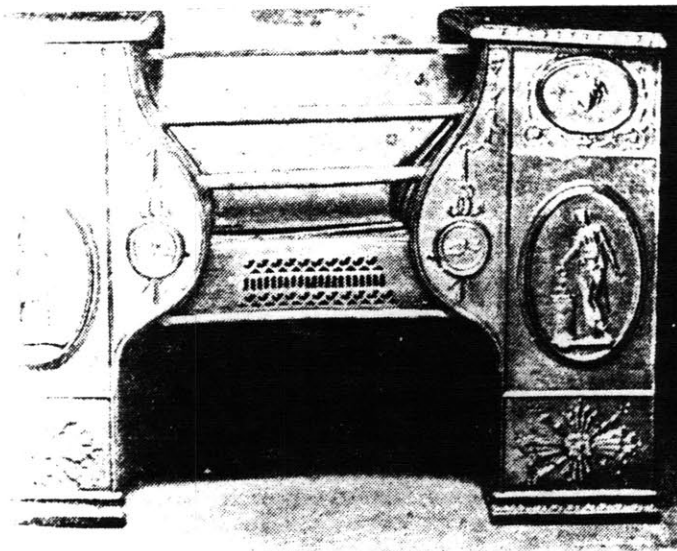


Fig. 53: The hob grate was designed to increase the air flow underneath the fire.

A type of grate that was quite well known in England and often seen in this country at the end of the eighteenth century was the hob grate (Fig. 53). This was composed of a small coal grate or basket suspended between two short hollow metal piers called "hobs". The hobs restricted the width of the fireplace and allowed only a small opening below the grate for the draft. A "register" or damper was often placed in the flue above the grate to further regulate and increase the draft.⁴

The burning properties of coal presented some problems that became particularly acute when it was burned in open grates. Bituminous ("soft") coal, the type commonly used in England and the colonies, gives off a variety of volatile gases as it is heated to ignition temperature. In the common grate, where fresh coal is placed on top of the fire, these gases and the soot of partially burned coal (the product of insufficient draft, resulting in a "cool" fire), rise directly to the chimney. Thus a good portion of the heat value of the coal would be lost. (Manufactured coal gas for lighting, popular in the late 1800's, was made by distilling the gas from coal in a heated, closed vessel. The principal byproduct, coke, was then used as a heating fuel.)

The problem of inefficient, smoky coal-burning fireplaces vexed grate designers for years. Much of Count Rumford's work with fireplace modifications was done with coal-burning installations, and a substantial portion of his essay dealt with the proper installation of grates into "Rumfordized" fireplaces. He advocated placing a slight hemispherical niche at the back of the coal-burning fireplace to better reflect the heat into the room. The grate, made of iron and fitted into this niche, was to be made as simple and small as necessary to hold the coals.⁵

Though a properly built "Rumford Stove" would achieve fuel savings of one-half to two-thirds over conventional grates, the problems were by no means solved. Fresh fuel had to be added to the fire as often

as twenty times a day, and the fire would still tend to smoke and flame until the added coals were fully ignited. A great deal of attention was required to remove ashes and clinkers to keep the fire burning properly. There were many attempts to provide automatic stoking for grates, most of which were less than satisfactory. One of the better ones was Arnott's, in which a box below the grate would be filled with a day's supply of coal. The piston-like movable bottom of this coal box would be moved up as more fuel was needed. In this way the fire was fed from below, and the gases given off by the fresh coal as it heated were ignited and consumed by the fire above. The coal box itself was virtually airtight, preventing the fire from burning rapidly to the bottom of the coal supply. Arnott's grate was said to burn for 36 hours without attention. Not patented, it was widely copied, though the lack of an ample air supply from underneath made it smoky, as were most of the other "smokeless" grates patented in England in the mid-1800's. However, Arnott's underfeed principle offered a superior way of firing soft coal and was to reappear in underfeed furnace designs a half century later (see Chapter VIII).

It was not until 1884 that the problem of smoky grates was finally solved. Dr. T. Pridgrin Teale's "Economiser" controlled the draft from below by means of a simple box formed under the grate with an adjustable air shutter at its front. Cinders that fell into the box would be burned to ash and not wasted; the fire would clear itself and burn for 12 hours without attention. The innovations of this grate are essential features of the modern slow combustion barless grate that is in common use in Britain today.⁶

However, this invention came too late to have any impact on home heating in this country. By that time methods of central heating had advanced considerably and were becoming available to substantial portions of a population which, unlike the British, was eager to give

up the traditional open fire (indeed, many people had already done so) for a demonstrably superior way of keeping warm. Coal grates thus remained a characteristically British phenomenon.

THE COMING OF COAL

In 1800 wood was still the dominant fuel in the United States, providing about 94% of the country's energy needs for cooking, heating, the building of homes, barns, fences, bridges, etc. As late as the Civil War, railroad locomotives burned wood for fuel.⁷ The coal heating revolution in the United States really began around 1808, when Jesse Fell of Philadelphia discovered that Pennsylvania anthracite coal would burn without the supercharged draft heretofore thought necessary and gave more and better heat than Virginia bituminous coal.⁸ (Anthracite, or "hard" coal, is denser than bituminous, with a greater carbon content, and requires a hotter fire to maintain combustion. However, it burns cleanly giving off little smoke or volatile gases.)

However, despite these advantages, anthracite suffered from the same disability that had limited the use of soft coal: high price. The problem of transporting coal economically precluded its use by all but the well-to-do. Until the completion of railroad lines connecting the coal fields with the major population centers of the country, an event that did not occur until after the middle of the century, coal could be shipped long distances only by water, a not inexpensive proposition. Also, its cost rose dramatically the further to or from the wharves coal had to be carted.

Both as an efficient means of transportation and as major consumers of coal themselves, the railroads had a significant impact on the development of the coal industry. The increased production that they stimulated insured that a steady supply of the fuel would be available

both for industry and for the new home heating apparatus that was being perfected. And coal was an ideal fuel for these new devices which, with their enclosed fireboxes and controlled drafts, could burn it far more efficiently than could grates.

Anthracite, with its clean burning properties that required less careful attention to the fire, was particularly well suited to domestic applications (bituminous was usually used at larger plants where skilled firemen were on duty). With the major deposits in West Virginia and Pennsylvania now reached by railroad, anthracite by the late 1800's had assumed a position as the virtually universal first choice for home heating fuel in houses with central heat. As central heating spread to the masses, the reign of "King Coal" widened, its preeminence continuing until the end of the first World War, when a combination of circumstances led to major changes in home heating habits (Chapter X).

CHAPTER VII

CENTRAL HEATING IN ITS INFANCY: 1800-1850

Despite all the improvements in fireplace and stove design during the eighteenth century, the problems associated with them - smoking chimneys, poor ventilation, uneven heating and high fuel consumption -- continued to be commonplace. Even when those problems were more or less solved, as with a ten plate stove or Rumfordized fireplace, the basic limitation of the fireplace or coal grate remained -- it was essentially a point source of heat, warming by radiation those surfaces that were exposed to the fire in proportion to their distance from it. Homes or other buildings with many rooms could only be heated by placing a fireplace or stove in every room, a situation that in larger buildings demanded a tremendous amount of labor to keep the fires burning.

As the Industrial Revolution took hold in England and later in America, a new class of buildings came into being. The mills, with their vast rooms in which hundreds of people worked, proved impossible to heat with the traditional small grate or stove. Considerable productivity was lost as the workers had to go to the grates to warm their numbed hands. The cold was especially a problem for the children whose work consisted primarily of joining the ends of strands of cotton, silk or flax.¹ So it was in the vast mills, as well as in large public and institutional buildings and the homes of a few wealthy individuals, that the earliest methods of central heating were developed.

HOT AIR HEATING

The first type of central heating system to see any degree of widespread use was the hot air furnace. This was an ancient, though long forgotten, concept, dating back to the Roman "Hypocaust," in which the hot products of combustion were passed through ducts in the floors and walls, providing a form of radiant heating from a central source.

In England the first hot air central heating systems evolved directly from the stoves which were installed in mills around 1800 to replace the grossly inadequate coal grates. These were closed stoves of the "Holland" or "Dutch" type. The most popular variety was round with a domed top, suggesting a shell in appearance; hence its name, the "cockle" or "coakle" stove. To increase its efficiency in the mills it was enclosed in an outer casing of brick. Air passed up between the casings and, warmed as it passed over the stove, through flues to the rooms to be heated. Because these stoves were often overheated in order to obtain sufficient air flow, they proved to be an extreme fire hazard in the cotton mills, even when placed in a separate building.²

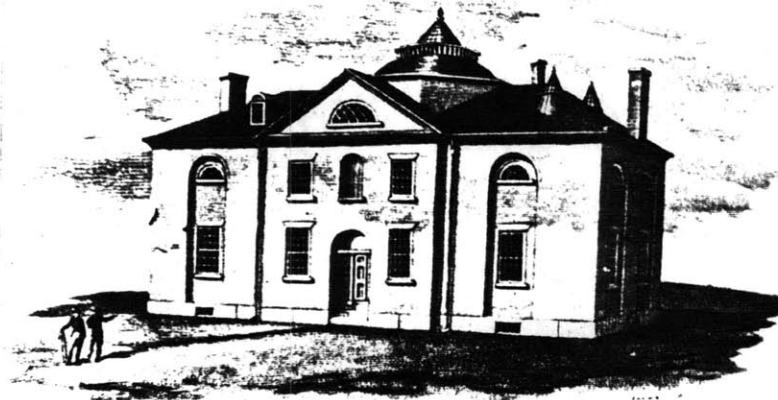
In this country institutional and commercial buildings were the subjects of the first experiments with hot air heating. Daniel Pettibone of Philadelphia was one of the first Americans to experiment and write on the subject of central heating by hot air. His treatise, Description of the Improvements of the Rarefying Air Stove, published in 1816, discussed various types of air, steam and water apparatus and their potential, though it is uncertain just how influential the book was. Pettibone's first installation of a "Rarefying Air Stove" was in the Philadelphia Bank in 1809. This system was probably similar to furnaces installed in the U.S. Capitol in Washington at about the same time.

The heating apparatus in the Senate Chamber there was very much like the British mill installations described above. A special iron stove was placed in a masonry vault below the chamber with flues or pipes carrying the heated air to the room above. Fireplaces or grates in the chamber itself provided additional warmth. A more elaborate system was installed by Daniel Latrobe, the Capitol architect, to heat the House Chamber, though by that time Latrobe was advocating using in the Capitol steam apparatus such as had been tried successfully in large halls in Europe. Charles Bulfinch, Latrobe's successor, tried to heat the Capitol Rotunda with hot air, but stoves and grates were the sole source of heat in the smaller rooms until a complete hot water system was installed by Captain M. C. Meigs later in the century. Another early hot air installation, also by Pettibone, was at the Pennsylvania Hospital in Philadelphia, in which six small rooms were warmed by one stove of moderate size.

The first building in the United States to be entirely centrally heated was probably the Massachusetts Medical College in Boston, (Fig. 54) designed by Jacob Guild in 1816. The installation there used a simple coal burning stove and was similar to that used in the Capitol. Registers in each room allowed the heating pipes to be opened or closed to admit warmed air as desired. Bulfinch's Massachusetts General Hospital, built in 1819, was heated the same way.³

A British article on hot air heating, reprinted in the Franklin Journal and American Mechanic's Magazine (Vol. 1, 1826), illustrates the general nature of these early hot air systems (Fig. 55).⁴

Such early hot air systems proved to be not entirely satisfactory, especially for institutions and other large buildings, and did not lend themselves at all to the long low textile mill spaces. Most of the difficulties arose from the lack of any means of inducing a forced draft



MASSACHUSETTS MEDICAL COLLEGE.

Fig. 54: The Massachusetts Medical College in Boston was the the first building in the country to be warmed entirely by central heating.

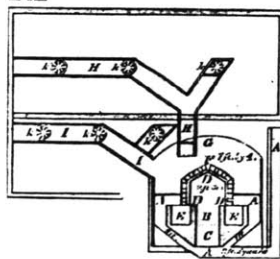
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Having used the Hydrostatic Blow-pipe for five and twenty years, we would be proud to speak in favour of its economy, with the exception of its use in the long trial. It was proposed that it would be found useful, to all artists who employ the blow-pipe in soldering, or in melting the tubes of thermometers, barometers, and other vessels in which the exsufflator lamp is applied. Connected with the large self-regulating reservoir of hydrogen, to be used in the next number of this Journal, it is, with the aid of a jet of compressed air, supplied to it in the compound Blow-pipe, composed of four plates; and the facility with which the hydrogen gas is produced, may be made to act in any convenient direction, as well as to be highly serviceable to soldering, coppering, and painting. In soft soldering, it is often far more effective than a red-hot iron. Its peculiar cleanliness is worthy of attention; in this respect, it greatly exceeds the ordinary blow-pipe flame. Besides, the air is peculiarly ample, when which it is susceptible of an instantaneous increase, or diminution, in size or intensity. I do not believe the heat produced in this way, to be much more intense than that produced by a lamp.

(See on conversion.)

WARMING ROOMS BY HEATED AIR.

The following mode of warming large rooms, with hot air flues, is recommended, and has had its utility established by the result of the trial.

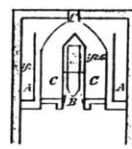


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For the purpose of warming, it is, in a room 20 feet long, 12 feet wide, with two very large fire-places, the pipes are probably warm ten yards from the fire. The flues, in this case, are adapted to the room, and a small quantity of hot air, 100 or 150 degrees, (say 100 degrees) kept at a regular heat of 20 degrees in one place, the flues with hot air. The existing fuel is very good, but the old plan, for the two rooms, would cause children nearly, the heated pipes, and it is not a saving of fuel. The whole expense of laying down a building the cellar, &c., was about one hundred pounds per year.

The following rough description will, perhaps, make the preceding clear to your readers.

The drawing, prefixed to this article, shows the two rooms, 20 feet by 12, and to the square of the roof 15 feet; the side by 12, and to the square of the roof 15. Also, a third a (the cellar beneath) containing the fire-places that furnish air in the rooms. A, is the cold air flue; B, fire-place; C, is the hot air flue; D, smoke flue; E, 4 1/2 inches brick-work, with small pipe, similar to chimney pipe, 5 inches in diameter, to admit cold air in the room, and to let it into the hot air, when heated; G, the hot air chamber; H, hot air flue; I, ditto into the small room; K, ventilates the heat.



The additional figure here inserted, is an elevation of the A, is the cold air flue; B, the fire-place; and C, the hot air flue.

ON THE FIGURE OF THE EARTH.

The subject of this Review is taken from the London Quarterly Review, and the facts for which work it was written, is the pen of Professor James Brinkley, of Columbia College, N. Y. It will, perhaps, be thought by some persons, that the only

Fig. 55: A British article of 1826 described early approaches to hot air central heating.

in the ductwork. High air temperatures were needed to induce the drafts. Thus the furnaces were generally overheated and produced an unpleasant, odorous, scorched air often containing ash particles. The superheated air tended to rise quickly to the ceiling of the heated rooms and stratify, adding to the discomfort. The lack of a forced draft also severely limited the length and placement of the ducts. For instance, 26 hot air furnaces were required to heat the main pavilion of the Pennsylvania Hospital for the Insane in 1840.⁵

Nor were these problems confined to installations in larger institutional buildings. Residential installations were likewise severely hampered. In Boston, houses constructed in the forties and fifties were only able to use a furnace to heat the main rooms on the first two floors, for it would have been impossible to get heat to the upper floors without severely overheating the lower ones. Rooms on the upper floors were heated with coal grates. (It should be noted that the top floor of the larger dwellings generally contained the servants' quarters. Perhaps one reason for that situation was that those floors could not be heated to the standards that the homeowner demanded in his own quarters.) The early furnaces did not have enormous heating capacity, as indicated by the fact that as late as the 1880's two furnaces were often required to heat a typical Back Bay house.⁶

HOT WATER HEATING

Like hot air heating, hot water heating dates from Roman times. The Thermae of Rome were baths heated by passing water through a coil of brass pipes which passed through the fire. This method of water heating formed the basis for the early hot water systems developed in France and England around 1800.

Hot water seems to have been first used in France by M. Bonnemain in 1777 for hatching chickens by artificial heat. The French Revolution disrupted further development in this field (as it did everything else), and it is not until 1817 that the next installation is reported. That was by the Marquis de Chabannes, who used a system similar to Bonnemain's to heat a conservatory and some small rooms in a private house. In 1818 he published a pamphlet describing this system and some proposed modifications to hot air stoves.

Across the English Channel in 1822 Bacon used hot water to heat his forcing houses. The system used a single, large diameter pipe set at a slight incline. Hot water rose along the upper part of the pipe and cold water returned along the bottom. As one might imagine the system did not work very well; a Mr. Atkinson almost immediately suggested using a second pipe for the return, thereby making the apparatus very similar to Bonnemain's of 35 years earlier, except that Bonnemain used small bore pipes and Atkinson's were four or five inches in diameter.⁷

The even heating properties of these low-pressure hot water systems gained them favor for many applications, particularly greenhouses, over the steam systems that were also beginning to emerge at that time. These systems were of two types. With an open boiler (analogous to a pan of water on a stove) there was no danger of explosion. Heated water circulated in a closed tube by siphon. Closed boilers were similar, and had the advantage of beginning circulation as soon as the fire was started. The expense of the boiler and the slow circulation that resulted from low system heights were drawbacks.⁸ The large diameter pipes required of such systems were unsightly. This problem was soon to be solved by Angier Perkins, an American by birth who emigrated to Britain in 1827 and quickly found himself interested in the heating business, which was far ahead of anything in the U.S. but still

not making headway due to the common prejudice against large pipes.

Perkins developed a system using water heated under pressure to 350°F. which would then circulate rapidly through small bore pipes. For these he used pipes manufactured by Russel's of London for gas piping (manufactured gas was just then coming into common use in Britain). This pipe had evolved from that made earlier from Napoleonic War surplus rifle barrels. The Perkins system, patented in 1831, was an endless circuit of pipe. Water was heated in a coil in the furnace and then carried to the highest point in the system. From there it moved downward through coils or closed vessels which served as radiators in the rooms to be heated. (Fifty years later, John H. Mills was to apply this same principle of downward supply to steam heating.) The small pipes could easily be hidden in pedestals, etc., or even wound around the room behind a perforated skirting board (baseboard), which allowed the heat to escape, a predecessor to the baseboard hot water convector introduced 100 years later. These features dispelled earlier prejudices against hot water and produced many testimonials from satisfied users. It was installed in a number of buildings but was very expensive due to the individualized nature of the installation. Critics pointed out the danger of explosions resulting from overheating. Though designed for 350°, temperatures as high as 550° were often reached, and even the manufacturer was forced to admit that careful supervision of the system was absolutely essential. The high temperatures often caused odors and posed a danger to any nearby combustible material. Still, between 1830 and 1840 the Perkins system was the best achievement in the art of central heating.⁹

STEAM HEATING

Steam gradually replaced other methods (mostly stoves) of heating larger buildings in England between 1800 and 1810. First tried in greenhouses, the method was tremendously extended after it was first

used in a cotton mill in 1799. One reason for this popularity was that in mills that used steam power for the machinery the exhaust steam provided a ready and economical source of heat. The steam was distributed by huge iron pipes running down the middle of the workroom or suspended from the ceiling.

James Watt is credited with building the first steam radiator. It was a tin box about $3\frac{1}{2}$ feet by $2\frac{1}{2}$ feet by 1 inch thick, with a cock to let out the trapped air, connected by a single pipe at its lower edge to the boiler. Watt used this creation to heat his study. Boulton, Watt's partner, heated a room in his home with a similar device.

Count Rumford, upon his return from Bavaria in 1801, developed a plan to heat the lecture room of his Royal Institution by steam. He used eight inch diameter copper tubes to carry the steam from a boiler on the ground floor to three foot diameter copper drums in the room. The drums allowed for expansion in the pipes and collected the condensate, which was carried back to the boiler by smaller tubes.¹⁰

Shortly after Rumford's installation, Mr. Lee of Manchester, whose mill was the first heated by steam, had Boulton & Watt install a steam system in his house. The staircase, lobby and halls were heated by air rising from the "steam cylinder" below; the dining room by ornamental cast-iron vases filled with steam; the bedrooms by steam pipes also made of cast iron.

Between 1810 and 1815 there was a great increase in the use of steam for mills, public and commercial buildings. By the 20's the methods of central heating were well known but used sparingly in houses and the better class of public buildings, generally only in the halls and stairways, with the other rooms heated by grates. The English

gentleman regarded steam as extravagant and unsuitable and continued his devotion to the open fire, with its waste of fuel and demand of labor to attend it. Most Britons still accepted an indoor temperature of 50° as healthful and proper.¹¹

Central heating was adopted and accepted much more quickly in the United States. The colder and more extreme New England climate quickly dispelled whatever cultural prejudices had been carried across the Atlantic. As was the case with stoves, new methods of central heating were readily adopted by those who could afford them. Though it was not until near the end of the nineteenth century that central heating came economically within the grasp of the masses, it was in New England where the problem of heating the homes of ordinary people by steam and hot water was successfully solved.

As in England the first steam heating installations in America were in institutional and mill buildings. The first known system was at the Middletown Woolen Manufacturing Co. in Connecticut in 1812. There exhaust steam was passed through copper pipes in the mill building. In 1813 in Baltimore a factory was fitted with a similar steam system. All such early installations were probably similar, with exhaust engine steam circulated overhead in 3" to 10" diameter iron pipes. No great advances in steam heating appear to have been made prior to the introduction of high pressure steam in 1842.¹²

The foremost pioneers in the early development of steam heating were the firms of Walworth and Nason in Boston and Tasker and Morris in Philadelphia. Walworth & Nason took over the New York branch of Russell's, the British pipe manufacturer, in 1841, and the following year moved to Boston to capitalize on New England's colder climate by going into the heating business. Their first heating work was probably the counting room of the Middlesex Mill in Lowell. Nason turned to the

problem of using small bore piping in a steam system and by 1845 had overcome the difficulties. The firm's first steam installation was the Eastern Exchange Hotel in Boston, done in 1845 as was a woolen mill in Burlington, Vermont. Numerous other orders soon followed. At first Walworth & Nason bought their pipes from Russell's, then from Tasker & Morris, and finally manufactured their own. When their own Wanalancet Tube Works failed in 1852 the partners separated. Nason, who moved to New York due to ill health, became recognized as one of the foremost authorities on heating in the United States. His system for heating and ventilating the Capitol in Washington, installed in 1855, has been described as "the first really scientific and complete job of its kind done in this country."¹³

Though many fine houses were heated with steam by the 1850's, including the White House, the method was mostly limited to commercial and public buildings. Exhaust steam was an economical source of heat for factories, but the high cost of installing a boiler and the careful and individualized installation of the distributing pipes made a complete steam or hot water system very expensive and offset the not inconsiderable saving of fuel. Though less labor was required than to attend the many grates typical of a large dwelling, the high pressure was considered a danger and the attention of an engineer or skilled mechanic was felt necessary.¹⁴ The revolutionary developments that would popularize steam heating were yet to come.

A list of central heating manufacturers at mid-century gives a good indication of the size and nature of the industry at that time (Fig. 56). The preponderance of hot air system manufacturers shows the relative states of advancement of the various kinds of systems. Bearing in mind that most of the firms listed must have been small operations, the list clearly illustrates that central heating was in a highly experimental state, with a small number of firms (nineteen) operating only in the major centers of population and wealth.

Fig. 56 TENTATIVE LIST OF EARLY CENTRAL HEATING MANUFACTURERS

<u>Name</u>	<u>City</u>	<u>Earliest Reference</u>	<u>Type</u>
Robert Annesley	Phila.	1814	Hot air (?)
Benjamin Blaney	Boston	1845	Hot air
Blaney Steam Heat	Boston	1845	Steam and Hot water
Gardner Chilson Co.	Boston	1831	Hot air
Culver Furnace	Hartford (?)	1845	Hot air
James H. Deas	Phila.	1839	Hot air
Fox's Improved Patent Hot Air Furnace	Boston (?)	1844	Hot air
Golden Eagle (Charles Williams)	Phila.	1835	Hot air
Herman's Hot-Air Furnace	Boston	1851	Hot air
The Hitchings Company	New York	1844	Steam
Moore & Harkness	Phila.	1814	Hot air (mfgd Pettibone's)
Morris, Tasker & Morris	Phila.	1846	Steam & hot water, pipes & fittings
Danile Pettibone	Phila.	1810	Hot air (early inventor)
Moses Pond & Co. (After 1889: Boston Furnace Co.)	Boston	1829 (?)	Hot air
Pryor	Phila.	1814	Rob't Annesley's device
Daniel Stafford (Probably one of the first mass producers of furnaces)	Boston	1823	Hot air
George Walker	New Haven	1844	Hot air
Walworth & Nason (One of the first companies to specialize in steam heat)	Boston	1841	Steam
Elbridge Williams	Palmyra, N.Y.	1841	Hot air

Source: Walbert, Benjamin L., "The Infancy of Central Heating in the U.S.: 1803 to 1845,"
in Bulletin of A.P.T., V. 3 #4, p. 85-86, 1971.

CHAPTER VIII

THE RISE OF HOT AIR HEATING

In the second half of the 19th century the practice of hot air heating became the first central heating method to win a wide degree of public acceptance. While there were a few technical innovations during this period most of the progress was in the area of refining and simplifying the apparatus to bring its cost and operating requirements within the reach of large numbers of ordinary people.

A furnace installed in the John Stryker House in Rome, New York, at mid-century graphically illustrates the size and complexity of the early hot air systems as well as showing a highly advanced means of heating the air passing through the furnace. The house, razed in 1971, when the accompanying picture was taken, was built in 1839 and was originally heated by fireplaces in each room. The furnace, dated 1851, was installed when the later library wing was added.

That furnace, manufactured by the H.G. Giles Company of Rome, was apparently similar in construction to others being manufactured at that time. It consisted (see Fig. 57) of a centrally located metal firebox surrounded by inner and outer plenums of brick. Metal ducts which carried hot air to the rooms were located directly over the firebox. Return air came into the top of the outer plenum, dropped along the arched walls and through openings at the base of the inner brick wall into the inner plenum, where it was heated and rose into the ducts. Registers were placed in the floor and walls of the rooms. The space between the studs in the walls was used as ducts to carry heat to the rooms on the second floor.

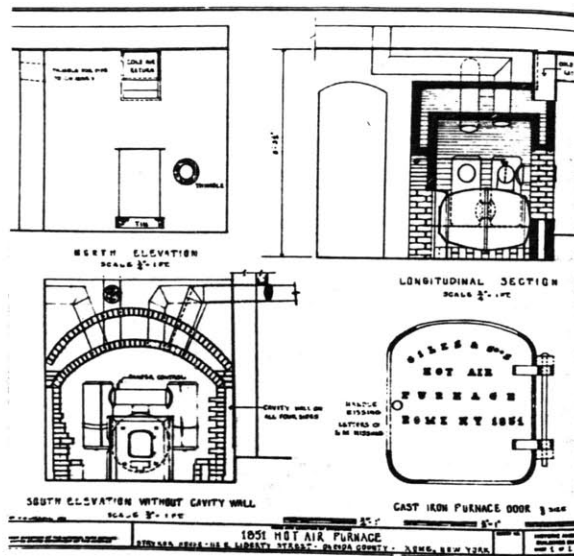


Illustration 1: Measured drawings of "1851 Hot Air Furnace" in the Stryker House, Rome, New York, measured and drawn in June 1971 by Orville W. Carroll, Architect, National Park Service.

Fig. 57.

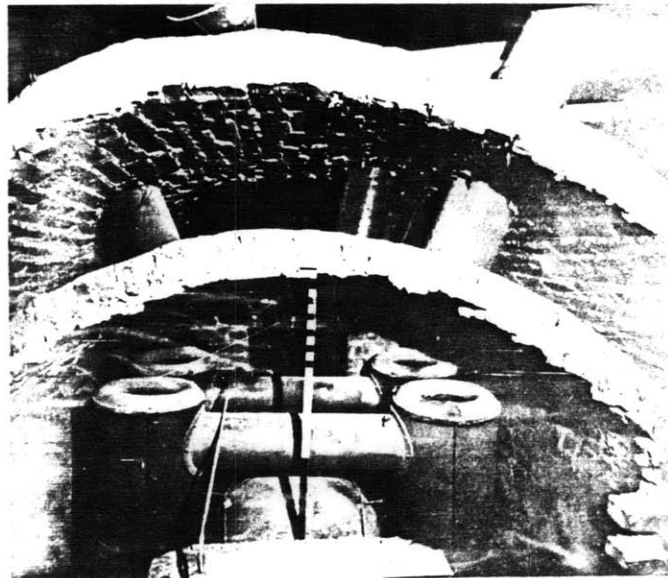


Fig. 58: Interior of furnace at Stryker House showing the inner and outer plenums and the sophisticated heat exchanger.

The furnace itself was made of several metal parts: the cast iron "pot-bellied" wood burning firebox consisted of two oval shaped sections with truncated ends and vertical end sections holding the fire and ash cleanout doors. The sections were joined by threaded metal rods running from front to back.

The most interesting and significant aspect of this furnace is the heat transfer "radiator" mounted atop the firebox (Fig. 58). This radiator consisted of two hollow sheet metal drums on each side of the firebox, connected to each other and to the firebox by lengths of eight inch stove pipe. A damper control, operated from outside the furnace, allowed the hot smoke from the fire to be diverted through these drums before it reached the chimney. In this way the heated surface area available to heat the air passing through the inner plenum was greatly increased. When a strong draft was needed for kindling the fire the damper control could be opened, thereby bypassing the radiator unit.¹

While there is no evidence of how well this device performed, it appears to have been remarkably sophisticated in its attempt to extract the greatest possible amount of heat from the fire. The basic form of this radiator device could be found only the best quality hot air systems before World War I, and was still being manufactured a hundred years later (see Figs 63& 64).

Another major advance in air systems, similar to the preceding in principle though not in execution, came during the 1850's with the development by Daniel Nason of the so-called "indirect" method, in which the air supplied to the rooms was heated by passing over coils of pipes which were heated by hot water from a boiler. The Hitchings Company of New York, which since 1844 had heated greenhouses by hot water distributed at low pressure through 2 inch pipes, offered the same system in the indirect method, for heating houses in the 1850's. (The indirect method will be discussed more fully in the following chapter

dealing with steam and hot water heating.) Hayward, Bartlett & Co., of Baltimore were also pioneers in this type of heating and made many installations in Washington government buildings. By the 1860's many firms offered such systems, considered the most modern of the time.

In a related development, Nason devised for the Boston Customs House a mechanical contrivance for propelling air over coils of 3/4 inch pipe and through flues to the rooms above -- the first known example in this country of heated air distributed by fans.²

By the 1860's the hot air furnace had been greatly improved and was a stiff competitor to the emerging steam and hot water systems. The "Tubular Furnace" of the Thatcher Furnace Company, manufactured after 1850, was a superior product, and the "Ruttan System", invented in Canada, included an excellent method of ventilation.³

A later invention was Samuel Gold's "Hygeian Heater", a sectional cast iron furnace that circulated air that was warmed to a moderate temperature by the same type of extended surface used on the Gold pin radiator (described later). The H.B. Smith Company of Westfield, Mass., took over its manufacture in 1873. The Hygeian Heater was a product that made sales in a difficult economic period and held up well in length of service. In 1878 one was installed "complete" in the Westfield High School for \$190.⁴

ADVANTAGES AND DISADVANTAGES OF HOT AIR SYSTEMS

By the turn of the century the use of hot air furnaces for heating residences and other small buildings in the United States had become very common. The primary reason for this was that, in comparison to the hot water and steam systems with which it was competing, hot air systems were mechanically far simpler and easier to install. This was reflected

in their cost; as little as one-half to one third that of other heating systems. The low cost had brought hot air central heating systems within the economic grasp of ordinary working Americans far sooner than steam or hot water.

There were of course other factors besides cost that made hot air heating attractive. Ventilation was a subject of great concern at the time, and an air system, which generally drew fresh air from outside to be heated rather than recirculating air from the house, was the only kind of heating available that integrated ventilation within the system. In mild weather a small fire in the furnace was sufficient to keep the house at a comfortable temperature, whereas in a hot water or steam system a hotter fire was required to keep heat flowing.

Still, hot air systems were not without their disadvantages. When only outside air was supplied to the furnace for heating, as was the common practice in 1900, the cost of operation was greater than with a steam or hot air system connected to direct radiation (indirect steam and water systems used more fuel than either their directly radiated counterparts or hot air). Only when warmed air from the house was recirculated through the furnace, as later became common, did hot air systems achieve the lowest operating cost.

Another problem, almost exclusively the result of sloppy or improper installation practices, was the contamination of the heated air by leaking flue gases. In a good quality, well designed hot air system the only serious problem was the difficulty encountered in heating the windward side of a house. This was caused by the differences in air pressure in the rooms resulting from the action of the wind on the house. Rooms on the windward side would have a higher than normal air pressure; those on the leeward side a lower than normal pressure. Air circulated through these hot air systems by gravity, that is, by the movement resulting from the pressure differences between hot and cold air, which were generally small. The weak natural draft of the typical hot air system resulted in the heated air going to the place offering the least resistance: the leeward side.⁵

Another problem resulting from the reliance on gravity to circulate the heated air was that the size of building that could be effectively heated by a hot air furnace was limited by the air friction encountered in the horizontal ducts. The practical limit for horizontal ducts was about 15 feet, which virtually necessitated placing the furnace at the center of the basement.

As has been noted, the low cost of hot air systems attracted many buyers, and to meet the demand many installers (and a few manufacturers as well) entered the field who either knew little of the proper installation practices or deliberately sold inadequate systems in order to turn a greater profit. A common mistake was to use a furnace of insufficient size to meet the heating requirements of the house, necessitating the maintenance of a very hot fire with its resulting high fuel consumption.⁶ Apparently these practices had a substantial impact on the furnace industry, for an 1899 editorial in The Metal Worker, a magazine of heating and allied trades, while noting that "a decidedly more favorable attitude toward them (furnaces) is manifested by the public," also had the following comments:

"One fact that has handicapped the hot air furnace trade has been the, all too often, ignorant way in which the furnaces have been installed and the piping run. Inefficient furnace plants can be found all over the country..."

and,

"Furnace work has been done altogether too much by rule of thumb, and in spite of the demand for a more scientific treatment of the subject of hot air heating very little literature has appeared on the subject. In fact there is no reliable and satisfactory work dealing with the topic of hot air furnaces and their installation."⁷

That last-stated need was soon met with the appearance of such works as William G. Snow's Furnace Heating (1915).

CONSTRUCTION OF THE FURNACE

Although there were many manufacturers whose furnaces differed in one detail or another, most furnaces were generally of the same type. They consisted essentially of a stove placed within a casing. Air was admitted to the space between the two where it would become heated, rise, and flow through pipes or ducts to the various rooms (Fig. 59).

Two kinds of casing, or outer shell, were common. While some larger units used a shell laid up of bricks, most furnaces used a less expensive metal shell, which usually consisted of two metal casings with a dead air space or asbestos insulation between them.

The characteristic of furnaces that varied the most was the length of the flue gas travel and the amount of radiating surface provided within the casing. For efficient operation the flue area had to be large enough to pass a large volume of gas at low velocity, permitting less forcing of the fire and thus lower heating surface temperatures, which aided in prolonging the life of the equipment. Longer flue passages were necessary to obtain the maximum heat transfer to the air that was circulated to the rooms.⁸ To accomplish this the better classes of furnaces had some sort of a radiator at the top through which the flue gases would pass before entering the chimney. Cheaper furnaces having no radiator were very wasteful, since much of the heat was lost up the chimney, but these found favor with certain builders "whose chief requirement is that a furnace shall have a large casing to deceive prospective purchasers as to its actual capacity."⁹

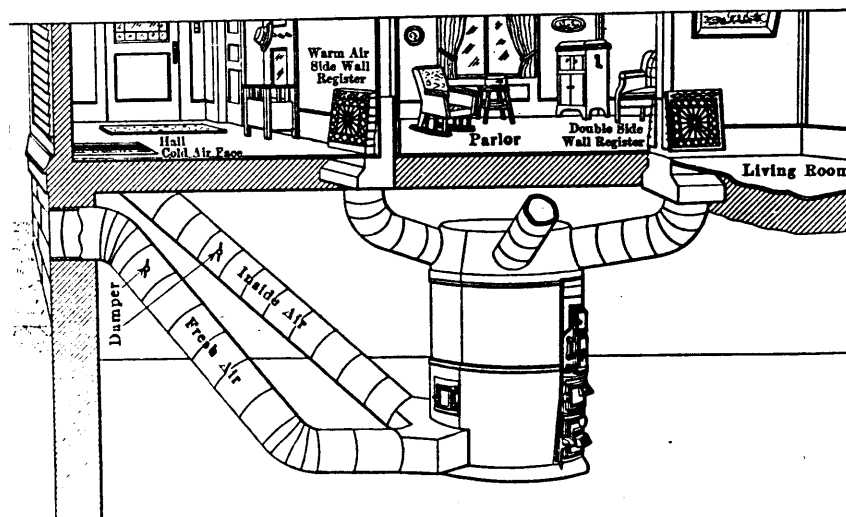


Fig. 59: Layout of a hot air heating system early in the 20th century. The inside air duct was a recent innovation; earlier systems drew their air entirely from outdoors.

The first step up in quality was to a furnace with a steel plate dome (Fig. 60). While better than a direct draft furnace, it still had little flue travel for the gases and was not as economical to operate as those having a radiator. This type of furnace could be an effective heater, though, and was apparently often used in the cheaper classes of dwellings.¹⁰

The simplest true radiator used on hot air furnaces was basically a cast iron "donut" that was fitted directly above the round firepot and combustion chamber (Figs. 61 and 62). The hot gases rose directly from the combustion chamber into the radiator and passed around the outer ring before entering the chimney. This type of radiator was entirely satisfactory (though not the optimum) for gravity furnaces with their low air velocities. The American Standard Company catalog listed a furnace with this type of radiator as late as 1951.¹¹

The best type of radiator available with hot air furnaces at this time was the "downflow" type (Figs. 63 and 64). The idea, in somewhat different form, is identical to that used on the 1851 furnace in the Stryker house. With this type the combustion chamber has a domed top. The hot gases pass through a side opening at the rear of the top and into the radiator. There they pass downward, often around a series of baffles, before exiting at the lower end into the chimney. This design's advantage was having a great deal of surface area which was "wiped" by the air moving up between the casings. The air that entered at the bottom of the casing was first heated by the cooler gases at the lower end of the radiator. Rising, the air would be exposed to the higher temperatures nearer the beginning of the flue gas passage and finally to the domed top of the combustion chamber, which was the hottest part.

Since hot air furnaces tended to dry the air as it was heated, most furnaces of the early twentieth century were equipped with some sort of

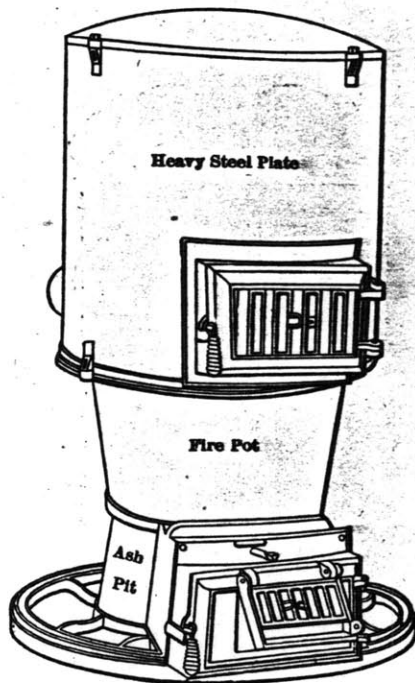


Fig. 2.—Furnace with Cast-iron Fire Pot and Steel Plate Dome.

Fig. 60.

Fig. 61: Top view of the cast iron radiator.

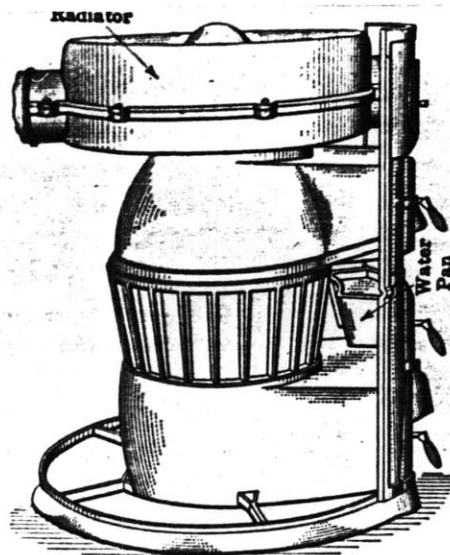
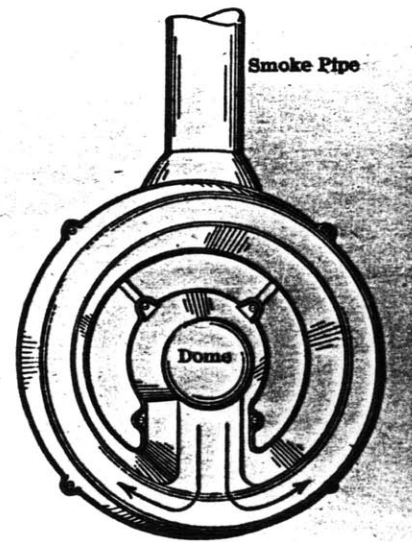
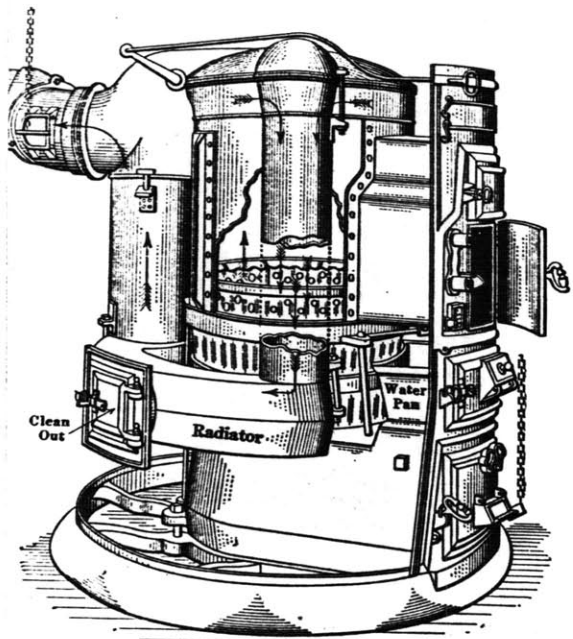


Fig. 62: Hot air furnace with top-mounted radiator (casing removed).



124.—Furnace with radiator near bottom (casing removed)

Fig. 63.

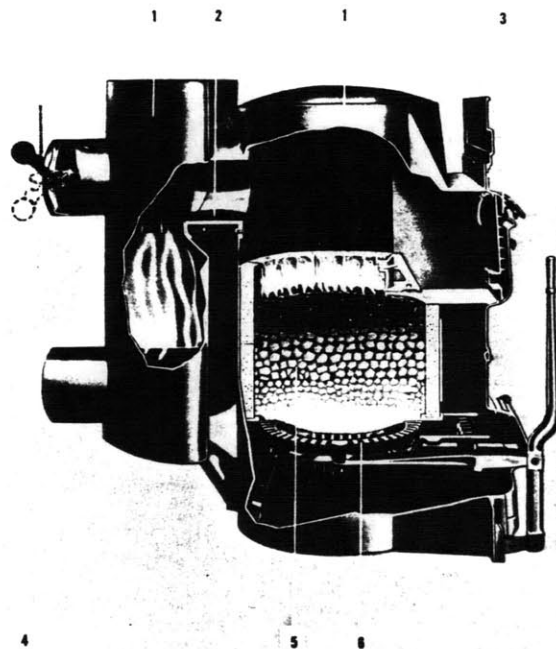


Fig. 64: Hot air furnace manufactured by the American Radiator Co. in 1949. Note flue gas passage.

evaporating pan within the air passage to add moisture to the air. Unfortunately, on many furnaces this pan was placed rather low, about at the height of the firebox door, and the air would be dried again by the time it left the furnace. The recommended practice was to place the pan above the combustion chamber and to supply it with water automatically using a tank and ball cock (Fig. 65).

The firepot was usually made up of cast iron sections and bore a strong resemblance to a pot-bellied stove. A firepot lined with firebrick was considered superior because it allowed a hotter fire with less deterioration of the furnace or contamination of the air supply due to the effects of the superheated iron. Within the firepot the coal rested on a grate, which had to be kept free of accumulated ashes and clinkers. For this reason a shaking or dumping grate which could be operated by a lever was preferred.¹²

OPERATION

Operating the furnace was a far cry from the carefree, automatic heating plants that we accept as normal today. As has been noted, coal was almost always used as fuel for home heating at the beginning of this century. Until the introduction of automatic stoking devices in the 1920's, the furnace was invariably fired by hand. This generally had to be done twice a day: in the morning to bring the fire up for the day's operation and before retiring at night to bank the fire. In colder weather or with furnaces having small fireboxes coal would have to be added more often throughout the day.

The morning and evening firetending chores encompassed a number of operations, all necessary to keep the furnace operating efficiently and at the desired temperature. First the grate had to be rocked (usually a mechanical device was provided to do this) to clear it of

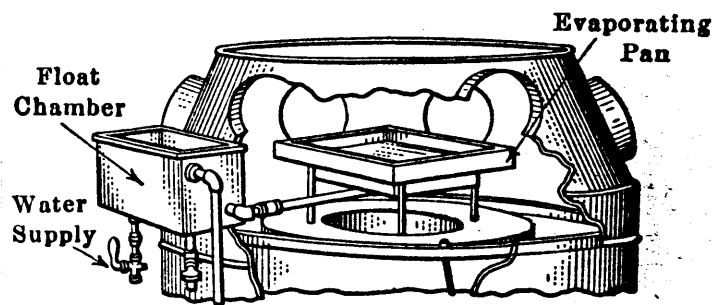


Fig. 65: Humidifier mounted atop furnace.

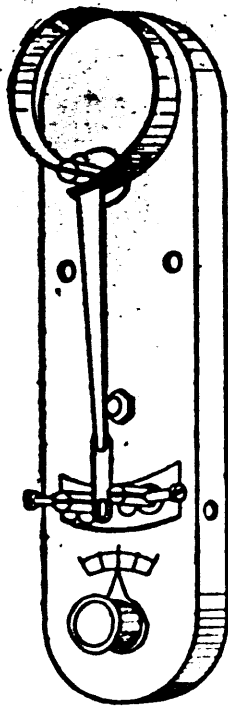


Fig. 66: Andrews thermostat. Expansion or contraction of the bimetallic loop caused the arm to contact one of the breaker points, operating a motor that caused the drafts to open or close.

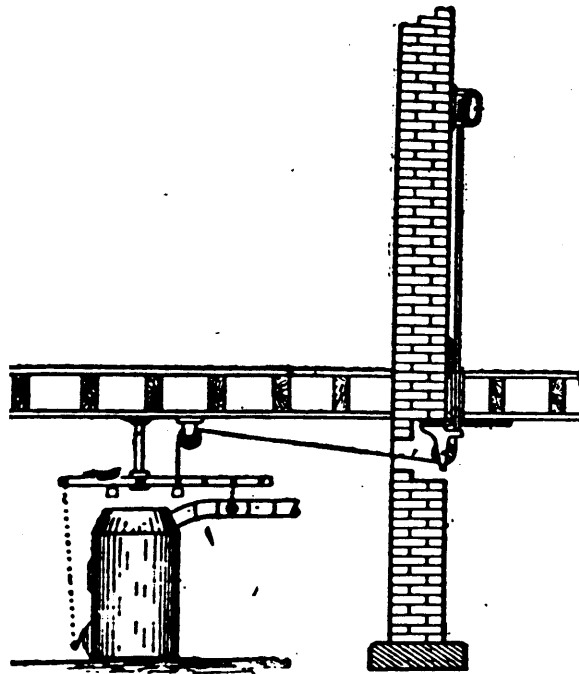


Fig. 67: Connection of the thermostat to the furnace drafts and dampers.

ashes and clinkers. Large clinkers had to be broken up and removed from the firebox. If the ashpit was full it had to be emptied and the ashes discarded; otherwise the flow of air to the fire would be obstructed. Care had to be taken in removing the ashes, for hot coals could fall through the grate into the ashpit. If not properly wetted down or discarded these could, and often did, start a fire. Fresh coal could then be added to the fire, taking care to distribute it evenly and not break up the fire. Then the drafts and dampers had to be checked and set for the desired rate of combustion. Lastly the water pan had to be checked and filled if it was not supplied automatically.

At night the procedure was essentially the same. Banking the fire for the night involved first cleaning it in the above-described manner, then pushing the coals to the rear of the grate and covering them with fresh fuel. The drafts would be set to be nearly closed and the fire door left partially open to maintain a slow rate of combustion overnight.¹³

REGULATING THE FIRE

There was, of course, no means for automatic ignition of the coal fire. If the fire ever went out it could only be relighted by building a fire of kindling wood in the firebox. This obviously was a time consuming and wasteful practice, so the fire was of necessity kept burning throughout the heating season, just as the early settlers had maintained the fire in the central fireplace, and thus some amount of heat was always supplied to the house. With the lack of fan-forced air delivery devices the only way of regulating the heat output of the furnace was to control the rate of combustion of the fire itself. This was done by adjusting the drafts and dampers that controlled the amount of air admitted to the firebox. After the turn of the century most furnaces were arranged so that the drafts could be operated from the living rooms above by means of a system of levers and cables.

Popular magazines of the period illustrated arrangements in which an alarm clock could be rigged to open the drafts automatically at a preset time in the morning.¹⁴ Such devices would at least bring the fire up before breakfast but in no way eliminated the morning firetending chores.

To maintain an even temperature in the house during the day some form of thermostatic control was often provided. Automatic control by a thermostat first appeared in mid-nineteenth century stoves and probably originated in Elisha Foote's patent of 1849. His stove was airtight; the thermostat was made up of bi-metallic rods that would expand with the heat and automatically close the draft.¹⁵

One of two types of regulators were used on furnaces. In the simplest the drafts were regulated directly by the temperature of the air passing through the furnace using a device similar to Foote's. In the other the drafts were controlled indirectly by changes in the temperature in the rooms above. In this type a thermostat placed in the room (usually consisting of a bi-metallic loop) would operate a battery or pneumatic circuit connected to a motor or diaphragm in the basement which in turn would operate the drafts and dampers through a chain or lever arrangement. Such a system is illustrated by the Andrews thermostat (Fig. 66 and 67). In either case the process merely served to control the combustion and had no connection to individual registers in the rooms. Still, by heating the building uniformly and avoiding periods of excessive hot or cold such temperature controls could afford operating economies of from 5% to 20%.¹⁶

FURNACE VARIATIONS

As was noted earlier, hard coal (anthracite) was the dominant residential heating fuel in the period preceding World War I. However,

furnaces were manufactured for other fuels and these were essentially similar in their operation to those discussed above, the modifications occurring in the design of the firebox.

The principal fuel in use other than anthracite was soft coal (bituminous). One type of furnace for burning soft coal was designed to admit a jet of heated air into the combustion chamber just above the surface of the fire (Fig. 68). This air-blast attachment, fitted between the sections of the firepot, had the effect of fanning the fire, causing the volatile gases and soot given off by the coal to be burned completely, thereby improving efficiency.¹⁷

Underfeed furnaces (Fig. 69) were also used with soft coal. Their principal advantage lay in the fact that the gases given off by the fresh coal as it ignited were burned by the fire above, the same result that Arnott sought to obtain with his self feeding grate. The lever-operated feeding mechanism simplified the routine adding of coal to the fire and was a forerunner of the automatic stoking devices that came on the market in the 1930's.¹⁸

The basic hard coal furnace could also be arranged to burn gas (presumably manufactured gas, for natural gas was not widely available in 1900) by the addition of a gas burning ring in the firepot (Fig. 70). This furnace was claimed to burn either coal or gas without any further changes whatever.¹⁹ However, the firebox configuration of a furnace designed for coal was not right for efficient burning of gas, and the resulting inefficiency coupled with the high cost of gas increased operating costs on the order of 20%.²⁰

Furnaces for burning wood, such as that shown in Fig. 71, were generally very simply constructed with little attention paid to their efficiency, since the cost of fuel where they were used was usually

Fig. 68: Furnace with air-blast attachment for burning soft coal.

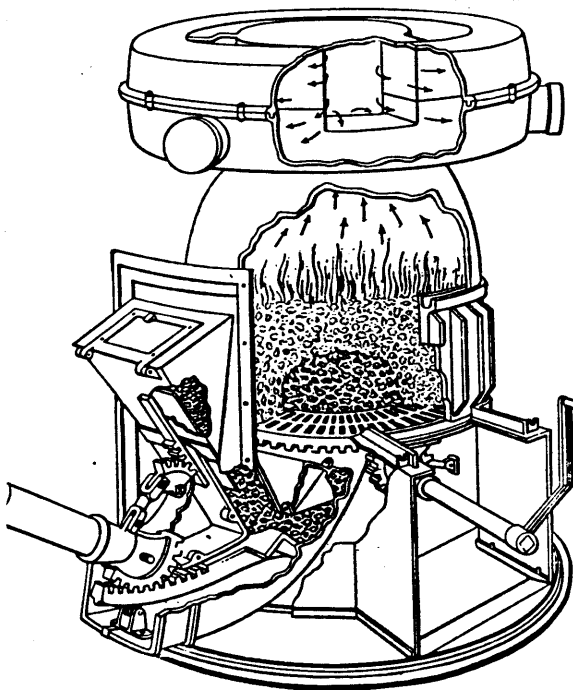
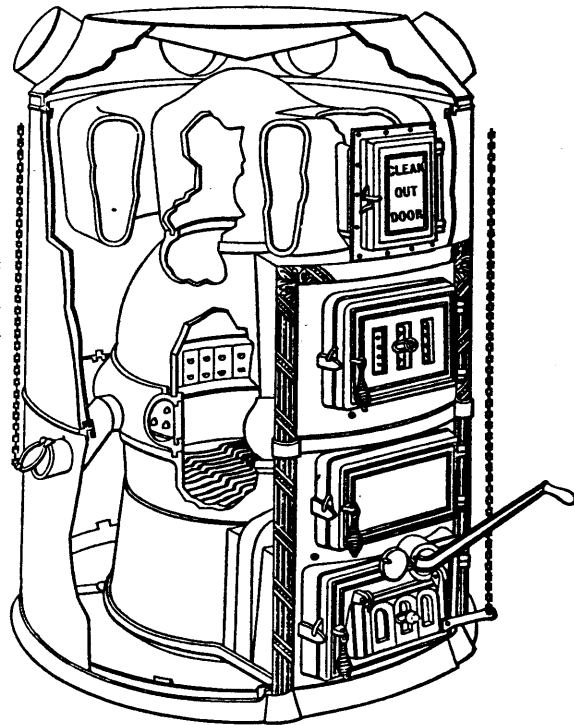


Fig. 69: Underfeed furnace. Coal was loaded into the hopper and fed to the firebox by operating the lever at the left of the picture.

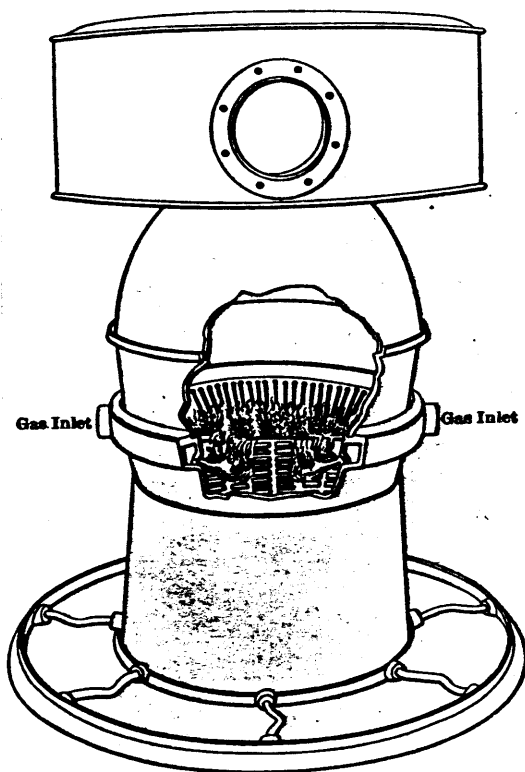
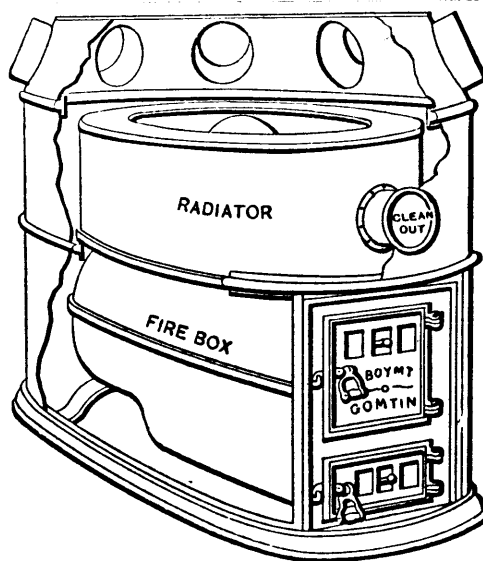


Fig. 70: Furnace with gas burning ring in place. The large ring at the bottom is the base for the casing.

Fig. 71: Wood burning hot air furnace.



very low. Larger sizes were built to take four foot long cordwood pieces, though smaller sizes were also available.²¹

The limitations inherent in the basic design of the hot air furnace led to some variations to extend its capabilities in certain situations. In larger houses "twin furnaces", two furnaces having a single top, were sometimes used (Fig. 72). Though more expensive than a single larger unit, this arrangement had the advantage of a greater range of heating capacity and was more manageable in moderate weather, being less likely to overheat the house.²²

A method that was sometimes applied in houses having rooms too remote to be successfully heated with hot air was the combination heater, with which some rooms were heated by hot air and others were heated directly by hot water radiators in the rooms. The hot water was supplied from a coil placed within the furnace. Circulation of both the air and water was by gravity and Hoffman notes that, "considerable difficulty has been encountered in properly proportioning the heating surface of the furnace to that of the hot water heater, and the systems have not come into general use."²³

One variation that appeared frequently after the war in smaller houses, particularly in the midwest, was the "one pipe" or "pipeless" furnace. This was simply a conventional hot air furnace, but it was installed with a register opening directly above it into the first floor of the house instead of the usual system of ducts. Return air was drawn from around the perimeter of the register back into the furnace casing. The pipeless furnace was only satisfactory in small houses, and then only if the doors to the rooms were left open to allow the heated air to enter (the single register was usually placed in the central hallway of the house).²⁴ Still, it was a cheap means of providing central heat -- in 1926 a Chicago outfit advertised pipeless hot air furnaces complete at \$62.92 to \$135.95.²⁵

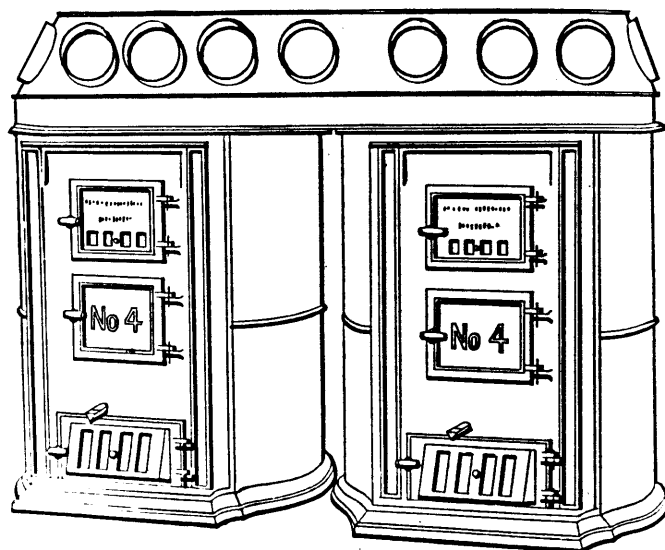


Fig. 72: Twin furnaces, also known as the "battery system."

One of the simplest yet most important developments in hot air heating during the twenties was to provide a means for recirculating air from the house to the furnace rather than heating only outside air. Previously it had been widely believed that the constant introduction of large quantities of fresh air were necessary to obtain proper ventilation. That practice was not without its cost, for the savings to be gained by using recirculated air were estimated to be as high as 30%. Supplying house air to the furnace became more common as people discovered that it did not seriously affect air quality, especially after the introduction of fan-forced systems with their built-in air filters.

FORCED AIR HEATING

The most important variation on the basic hot air furnace was the addition of mechanical devices to force the heated air through the system. Forced-air heating systems were first developed during the 1870's for use in large buildings having numerous occupants, such as factories, schools, hotels and auditoriums, where ventilation was genuinely a problem. These systems, as might be expected, were often huge, with large, steam-driven fans, and could not readily be scaled down for use in dwellings. However, the advantages of forced-air were apparent. The heated air was supplied under pressure, so that the detrimental effects of wind-induced differential pressures in rooms were eliminated, as could cold drafts, since the air pressure inside the building was higher than that outside, causing all air leakage to be outward. The systems were available with a number of accessories: air washers and humidifiers, automatic damper controls and brine cooling systems.²⁶

In the B.F. Sturtevant Co. catalogue of 1860 (Sturtevant was a pioneering manufacturer of fans and blowers for heating large buildings by warm air) there was illustrated (Fig. 73) the embryo of an idea

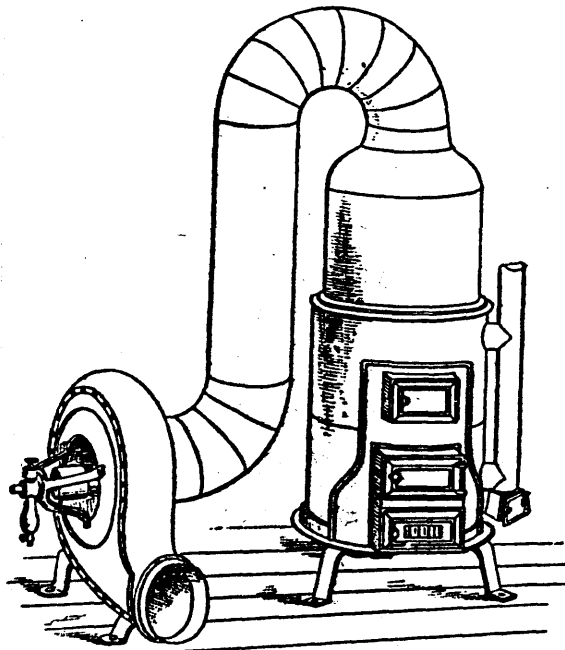


Fig. 65.—Embryo Idea of a Fan Furnace Apparatus, 1870.

Fig. 73.

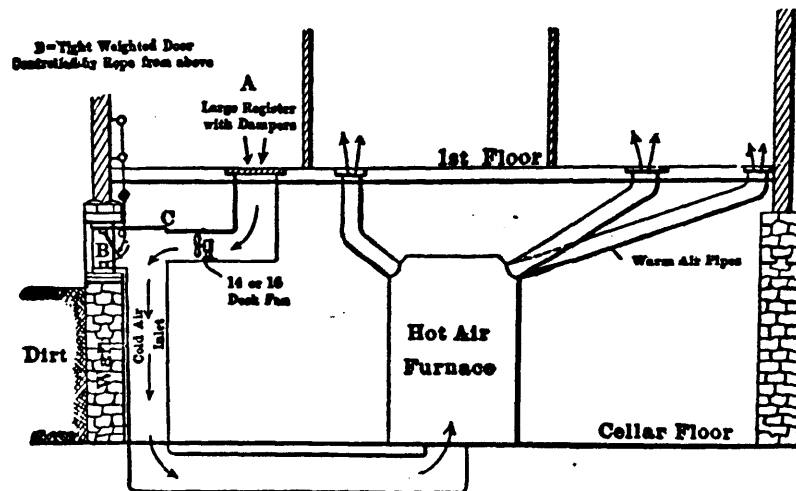


Fig. 71.—Mr. Jewett's Sketch Showing Fan Used with Furnace.

Fig. 74.

for a small fan furnace apparatus. There appears to have been no general application of such a device.²⁷

Snow reports on several articles that appeared in The Metal Worker around 1915 that dealt with the idea of using a fan with furnace heating. In one the writer advocated an extended surface of vertical ribs or flanges in the furnace to increase its heat transfer surface when used with a fan. Several other articles described the use of a small office-type electric fan, of 12 to 16 inch diameter, placed in the cold air supply duct. One such installation, by F.H. Jewett of Chicago, is illustrated in Fig. 74. The primary benefit noted by the experimentors was the more rapid heating of the house in the morning. Great increases in furnace capacity were also noted, since the increased movement of air over the heating surfaces of the furnace allowed greater heat transfer, which heretofore had not been as complete as it could have been. In these first experiments the fan seems to have been switched on manually as needed.²⁸

In the early twenties homeowners were still tinkering with systems using ordinary household fans, but in addition heating manufacturers were beginning to carry out research on more sophisticated and well engineered methods. By the thirties these products began to reach the market. The Carrier "Weather-maker" of 1931 was a gas-fired, warm air furnace with a squirrel-cage blower fan that pulled air through the return duct and forced it through the furnace. The blower and air filter assemblies were essentially add-on devices attached to a conventional looking furnace.²⁹

In 1935 General Electric introduced a direct-fired "warm-air conditioner" that combined heating, humidification and air cleaning in one unit that was aimed at the small home market. Several other manufacturers, mostly based in the midwest, came out with similar

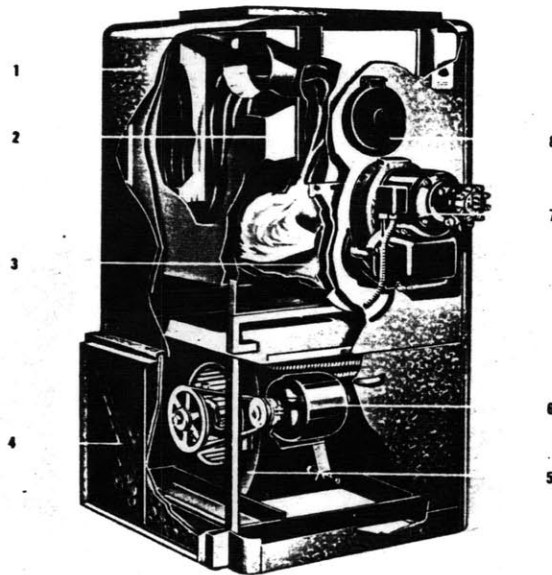


Fig. 75: Oil fired integrated warm air furnace and blower unit manufactured by American-Standard in 1951.

Fig. 76: TYPES OF HEATING EQUIPMENT IN USE, 1970

	Mass.	Northeast	North Central
Steam or hot water	60%	56.2%	16%
Warm air	23.5	31.6	64.5
Built-in electric	3.9	2.6	2.3
Room heaters	7.9	5.3	4.3

Northeast: Me., N.H., Vt., Ma., Ct., R.I., N.Y., N.J., Pa.

North Central: Ohio, Mich., Ind., Ill., Wisc., Mo., Iowa,
Minn., Kans., Neb., S.D., N.D.

Source: U.S. Census of Housing, 1970, V. 1, p. 526 & V. 23, p. 143.

equipment at about the same time. However, the cost of one of those complete units could run from \$450 to \$900 according to its complexity, and retrofitting an old house with ducts was often prohibitively expensive. The intensive advertising and public acceptance of radiator heat put these more expensive warm air systems at a disadvantage.³⁰ The simpler added-on blower unit and furnace combination remained the least costly alternative for the homeowner who wished to move up to a forced-air system and remained on the market into the 1950's, when the coal-fired home heating plant virtually vanished from use. The integrated system, specifically designed for burning oil or gas, incorporated a greater and more efficiently arranged heat transfer device, usually made up of formed steel, and became the industry standard after World War II (Fig. 75).

Warm air heating got a substantial boost during World War II, when all single-family dwellings authorized as "defense housing" were restricted to using some form of warm air heat. This was done primarily to save the metal that would go into heavier water or steam handling systems. The "Defense Housing Critical List" also reduced fuel consumption and stimulated the use of building insulation by strictly limiting the allowable capacity of the heating system according to the size of the house.³¹

USE IN NEW ENGLAND

Despite its advantages of low cost and simple operation, warm air heating is far less widespread in its use in New England than in any other part of the country. According to the 1970 U.S. Census of Housing (Fig. 76), only 25% of all dwelling units in Massachusetts had some form of warm air heat, against 60% having steam or hot water heat. In the North Central", or midwest, part of the country the figures are 16% for steam and water and 65% for warm air.

The reasons for these rather astounding differences are really quite straightforward. Until the advent of forced air, hot air systems were simply not capable of coping satisfactorily with the extremes of the New England climate, and steam and hot water systems were preferred whenever they could be afforded. The latter were not affected by the uneven air pressures caused by strong winds and generally had the greater capacity required to meet the extreme cold of New England winters. Furthermore, though many of the early experiments with hot air were carried out in this area, the perfection of hot air heating was really more of a midwestern development which spread east, whereas steam and hot water systems were first perfected and brought into production in the New England area. While earlier data does not seem to be available, it appears likely that the proportion of air systems now in use represents installations made after the advent of automatic, forced-air systems rather than the long-term state of affairs. Moreover, since a modern forced air heating system can be operated at about 15 to 20% lower cost than can a comparable hot water system, it appears likely that the trend toward warm air heating in New England will continue in the near future.

CHAPTER IX

STEAM AND HOT WATER HEATING COME OF AGE

"There are two great and unmitigated evils, that cling like a pestilence around the neck of individuals and society -- intemperance and boiler explosions, both reckless and needless squanderers of human life and happiness, the first largely responsible for the second."

-- John H. Mills
Heat ..., V. I, p.214.

During the second half of the nineteenth century the practice of steam and hot water heating advanced from an imperfect craft of limited application to a major industry placing highly developed apparatus into widespread use. While the earliest developments of this period were relatively small boilers, these remained expensive and thus saw limited application. The major advances and refinements that contributed to the growth of the industry were in larger boilers more suited to use in public and commercial buildings and factories. By the end of the century, with the industry well established and the methods of steam heating generally accepted, the practice of heating by steam and hot water began to reach the residential market as plants suitable for heating smaller dwellings were introduced at prices within the reach of the average homeowner. The following account of the development of steam and hot water heating is by no means inclusive, but rather illustrates the general current of events in the field.

The first major advance from the Nason and Perkins systems of steam heating can be traced to Stephen Gold, a Connecticut businessman and inventor, whose basic design, patented in 1854 and with improvements in 1856, consisted of a boiler piped to one or more radiators. The boiler

itself was a wrought iron shell with a cast iron internal firebox having cones to increase the heating surface. The radiators (Fig. 90) were much like Watt's of seventy years earlier and consisted of two thin plates fastened together by rivets in the depressions on one of the plates. It became known as the "mattress" radiator because of its appearance. The plates were sealed by rolling the edges with a piece of cord between them. Cocks were provided to admit steam and let out trapped air.

The real significance of the Gold system lay not in its basic design but in its advanced safety features. These were described by one writer thusly: "As far as we have any knowledge, this is the first attempt to make the boiler automatic. Mr. Gold introduced the automatic fire regulator and ... he applied a diaphragm to operate the safety valves, and also had an open glass pressure gauge connected to the boiler just below the water line ... and in case everything else failed to keep the pressure down, this acted as an automatic blow-off."¹

The system was immediately put on the market by the Connecticut Steam Heating Company of New Haven, which was organized in 1854 expressly to manufacture Gold's patent. It continued to be manufactured, with slight changes, in as many as seven different sizes almost to the turn of the century. A price list printed after 1896 still pictured the "mattress" radiator and stated that , "no other boiler has given such general satisfaction for such a length of time." Despite its popularity, the Gold system was not without its shortcomings. The mattress radiator was noisy, unsightly and inclined to leak. The boiler was too small for use in large houses, which comprised much of the market for central heating at the time, and was more expensive than it would have been if made entirely of cast iron. The complete lack of a ventilating system was a drawback among a populace still greatly concerned about adequate ventilation.²

An even greater breakthrough in boiler design came in 1859, when Stephen Gold's son, Samuel, patented a boiler constructed on an entirely new principle (Fig. 77). His boiler was made up of similar cast iron sections -- flat, oblong boxes -- which stood vertically in series with end sections to close and complete the unit. From the firebox the products of combustion were carried upward through tubes which were surrounded with the water of the boiler. As the water boiled the steam was forced through pipes into steam chambers, flat cast iron sections which in the earliest installations were grouped in an enclosed space directly above the boiler. A supply of fresh air passed through this space, around the steam chambers and, thus warmed, was carried by flues to the rooms above. This was the so-called "indirect" method of heating. In moderate weather it was not necessary to make steam as the outer surfaces of the boiler furnished sufficient warmth at the temperature of the water within. As a combination of a water and a steam agency in one apparatus the system was unique. Retaining the safety features of Gold's 1854 boiler, the apparatus was safe and simple. Its sectional construction, now almost universally used in residential boilers, gave it elasticity in size for use in large or small buildings. The sections were small enough to be carried through the narrow doors of older buildings for assembly on site. The warm air at the registers was never hotter than boiling water, in contrast to the often scorched air provided by hot air furnaces. The fresh air provided by the system supplied the building with complete ventilation (in this respect it was similar to and perhaps derived from Daniel Nason's).³ As the first cast iron, fire-tube, sectional boiler to be used for heating with steam it became a phenomenal success.⁴

Unlike Stephen's older design which could be manufactured by any small shop that handled wrought iron and small castings, the new Gold boiler required a large foundry capable of making the large castings.



1. The original Gold Boiler — first boiler to be manufactured by H. B. Smith & Co. — in its first form consisted of an assembly of vertical cast iron sections held together with draw bolts and gasketed at the joints. The very first model, introduced in 1859, was known as the "Eight Flue D" and was succeeded by other variations such as the "Ten Flue A" and the "Long Bolt B". These boilers were invariably installed in brick chambers and fed steam to indirect pin type radiators in the same chambers thereby warming air which was duct conducted to the rooms. Steam also could be fed directly to crude radiators or pipe coils in more distant rooms.

Fig. 77.



THE DREAM HOUSE OF 1887
A Gold boiler heats the principal rooms by the indirect method, through registers, while two Reed radiators supply additional heat in the third story.

Fig. 78.

That situation led to the introduction of H.B. Smith & Co. into central heating, a field in which they would be pioneers for many years.

H.B. Smith, a bookseller and storekeeper, acquired the Woronoco Foundry at Westfield, Mass., in 1853, probably more as a real estate investment than anything else, and in partnership with his brother began producing brass and iron castings. They specialized in ornamental iron-work such as railings but offered a broad range of machine parts as well. In 1859 the Smiths purchased limited sales rights (for western Mass.) and exclusive manufacturing rights to the new Gold boiler. In the summer of 1860 the patterns arrived at the Westfield foundry and the Smiths began accepting orders. The first year saw sales of only 15 boilers, with a value just over \$5000, but by 1862 sales had risen to 33 with a value of \$15,000. About this time they acquired national sales rights for the system.⁵

Described by H.B. Smith as "a new method in dwelling warming," Gold's system made a marked impression on a public that had money to spend (the Civil War had brought an era of prosperity) and the ambition to put up impressive public buildings and houses that were strictly up-to-date. At that time fireplaces, grates, stoves and hot-air furnaces were all used for house heating but each method had its serious drawbacks. Low pressure hot water systems were clumsy and inefficient for dwellings partly due to the lack of a satisfactory radiator. Walworth & Nason type steam and hot water systems were expensive and required competent supervision. So the Gold system offered for the first time the possibility of steam heating in homes of middle income citizens. Of the first 15 boilers installed by Smith, the cost ranged from \$200 to \$575, with an average cost of slightly over \$400.⁶

The earliest Smith installations were in private residences but orders for heating public buildings soon followed. Among the early clients were such notables as James Roosevelt of Poughkeepsie, who bought two boilers for \$1500 in 1864, C.L. Tiffany of New York, and Cornelius Vanderbilt. Gold systems were installed in Boston's new Horticultural Hall (cost: \$2480) and City Hall (cost: \$9520) in 1865. To promote the system the Smith Company published in 1869 a 64 page pamphlet entitled Home Comfort, including 50 testimonial letters from enthusiastic patrons. The complete Smith heating outfit offered a boiler heating steam or hot water, indirect radiators combined with a ventilating system and direct radiators for additional heat in distant rooms or in colder weather (Fig. 78) and carried the trade name of "Union Steam and Hot Water Heating Apparatus."

The introduction of a practical and economical steam heating system made possible the modern style apartment building, the first of which was built in New York in 1870.⁷

Of course the Golds and H.B. Smith & Co. were not the only people pioneering in the field of central heating. During the 1850's and especially the 1860's a great number of patents for heating systems were recorded; the Gold systems stand out because they were commercial as well as technical successes. Among the other major contributors to central heating during this period were Morris, Tasker & Morris of Philadelphia, who were familiar with Walworth & Nason's work from the beginning. Richard T. Crane of Chicago, who started a brass foundry in 1855, applied for several patents in the heating field, including one design in which the boiler and heating surface were combined and enclosed, along with the firebox, in brickwork, forming a unit from which the ducts emerged. Baker & Smith of New York were the first to bring out a water tube boiler combined with a box coil for indirect heating by steam.⁸

The idea was not immediately successful but the principle of the water tube boiler was correct, since the cast-iron fire-tube boiler could at best never take more than low pressures in steam, a circumstance that limited its use to buildings of modest proportions.

It might be well at this point to explain the difference between a fire-tube and a water-tube boiler. In a fire-tube boiler the products of combustion pass through tubes which are surrounded by a body of water. Exactly the opposite is the case in a water-tube boiler, in which the flue gases pass around tubes that are filled with water.

The idea of a water-tube boiler was by no means new in the 1850's. The little boiler that John Stevens built in 1788 for use with his marine engines was the first multitubular boiler on record. Joseph Nason in 1851 constructed a small, upright water-tube boiler to replace the coils of wrought-iron pipe inside the furnace that were characteristic of his early work with Walworth. The Baker and Smith water tube boiler became a pronounced success during the 1860's.

Sectional water-tube boilers (Fig. 79) appear to date from 1849, when George Brayton of Providence built his first experimental sectional cast-iron boiler. It was this Brayton design that formed the model for John H. Mills' first patent in 1867. Mills, who became one of the country's foremost heating experts, had great faith in cast-iron and in the principle of sectional construction and felt that both must be combined in a water-tube boiler. The first Mills patent was designed for use with an engine but others designed for heating soon appeared. Mills felt that his third boiler was the first really practical design. Its manufacture, he said, was begun by George W. Walker & Co. at Watertown, Mass. By March, 1873, though, the H.B. Smith Company had obtained complete control of the manufacture of the Mills boiler,

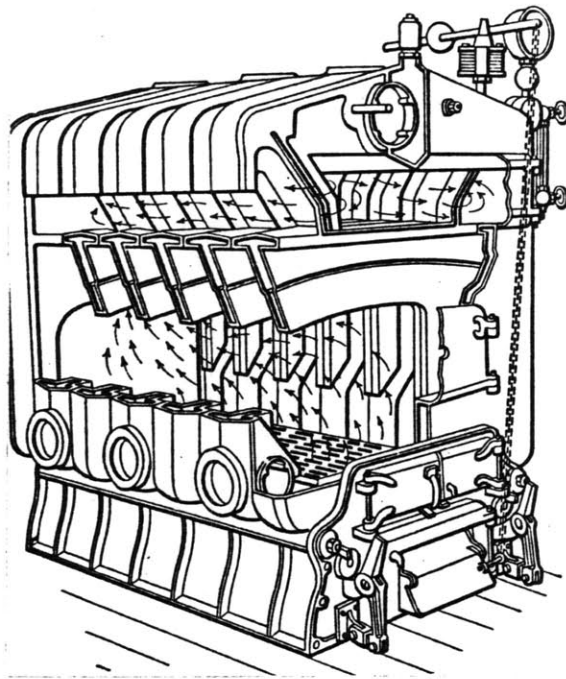


Fig. 79: Sectional cast iron water tube boiler. Arrows indicate direction of gas travel.

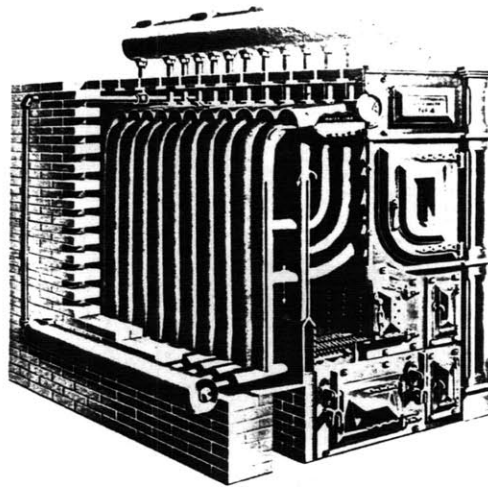


Fig. 80: The Mills boiler of 1873. The water was contained in the tubular sections. Arrows indicate gas travel.

2. By the eighties, the Gold boiler had become considerably more sophisticated. Exterior drums with nipple connections to the sections had replaced the old direct connection method although draw bolts were still used. The fire travel remained two pass through horizontal fire tubes formed by the sections themselves, with the smoke outlet discharging at the front of the boiler.

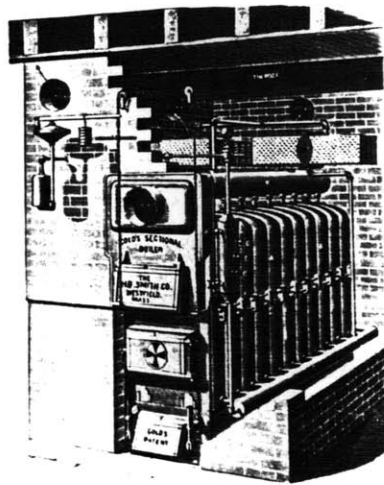
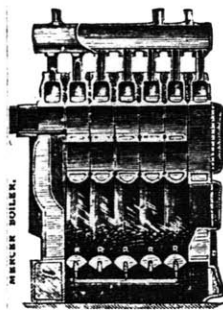


Fig. 81.



THE H. B. SMITH CO.

MANUFACTURERS OF

Steam and Water Heating Apparatus

For Public Buildings and Private Residences.

SPECIALTIES:

MERCER'S PATENT IMPROVED SECTIONAL BOILER,

For Hot Water and Steam Heating. Adapted for Wood, Hard or Soft Coal.

GOLD'S Improved Sectional Boilers.

"THE UNION" Hot-Water Radiators.

MILLS' Safety Sectional Boilers.

GOLD'S Indirect Pin Radiators.

REED'S Improved Cast Iron Radiators.

BRECKENRIDGE'S Pat. Automatic Air Valves.

Office and Warerooms: 137 Centre Street, New-York.

FOUNDRY: WESTFIELD, MASS.

Century Magazine, July 1891

Fig. 82: The Mercer boiler's smoke egress caused the hot gases to pass the length of the boiler three times.

probably due to the Smith Company's reputation for producing high quality cored castings.⁹

The Mills boiler of 1873 (Fig. 80) was a heavy boiler, designed for use in public buildings and businesses. Among its advances was its means of smoke travel, in which the smoke was turned to a vertical direction, exiting in side passages downwards into smoke flues below the grate level, in a manner reminiscent of Ben Franklin's original stove design. This resulted in much greater use of the heat generated by the fire. It had steam and water drums which acted as headers for steam (or water) and for returned condensation. These drums were joined to the boiler sections by nipple and locknut connections. Perhaps the most significant advance were the shaking or rocking grates in the firebox, which were soon vastly improved by John R. Reed of the Smith Company and became known as "Reed Shaking Grates". Such grates became universally used in all types of furnaces and boilers burning coal. These latter advances were quickly adapted to the older Gold sectional boiler (Fig. 81).¹⁰

The concept of gaining greater efficiency by increasing the smoke travel in the boiler found its way to the Gold boiler with the patent in 1888 of the Mercer boiler (Fig. 82), in which the flues of the Gold boiler were modified to double their length. The Mercer immediately became an important feature in H.B. Smith's advertising and sales.¹¹

Despite great advances in the art of central heating, the majority of small houses in America in 1890 were still warmed by stoves or grates burning wood or coal. In search of something better many homeowners were drawn to the hot air furnace by its low price (as was seen in Chapter VIII, the price was sometimes indicative of the quality obtained). There was a need and growing demand for a boiler designed to heat small houses that could compete in price with the hot air furnace. To meet this challenge John R. Reed patented in 1893 the Cottage

boiler (Fig. 83), which with a 16 inch grate sold for \$80 (furnace or boiler capacity at that time was indicated by the size of the grate). It was H.B. Smith's first real attempt to produce a boiler for the masses as well as the classes. Though cast in sections, the Cottage was a complete departure from the typical sectional boiler. Its three sections were firepot, base and dome. Larger sizes were added to the line as demand grew. Originally designed for hot water, the Cottage was later modified for steam and competed with the older designs in the Smith catalog.¹²

Another small boiler introduced by Smith was the Menlo (Fig. 84), which was originally made in 1895 in small sizes for domestic hot water service. After 1900 larger sizes of the same design were introduced for home heating. A number of these could be found in daily service a half century later.¹³ By 1918 the round cast-iron boiler of this type was the most common variety in residential heating service. Consisting of three to five main castings arranged vertically, the amount of heating surface and thus boiler capacity could be varied according to the number of intermediate castings used ("B" in Fig. 85).¹⁴

COMPOSITION OF THE INDUSTRY

The following list of major heating firms doing business around 1890 illustrates how the steam and hot water heating industry was still primarily centered in the northeast. It also shows that the early firms still dominated the field:

H.B. Smith Co.	Westfield, Mass.
Walworth Manufacturing Co.	Boston
A.A. Griffing Iron Co.	New York area
Hitchings Co.	New York area
Nason Manufacturing Co.	New York area
Morris, Tasker & Morris	Philadelphia
Bartlett, Hayward & Co.	Baltimore
Detroit Heating & Lighting	Detroit
Crame Company	Chicago

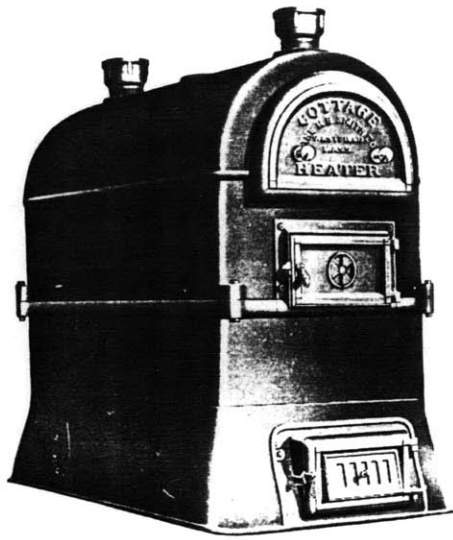


Fig. 83: The Cottage boiler, H.B. Smith's first attempt to supply steam heating for the masses.

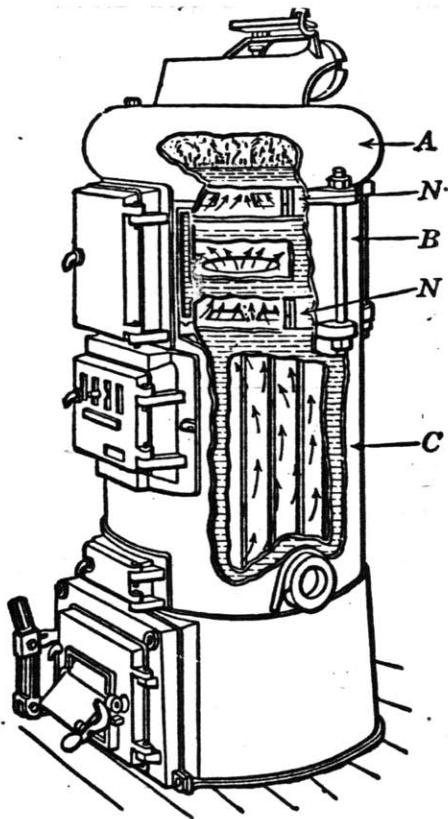


Fig. 85: A round cast iron boiler similar to the Menlo.

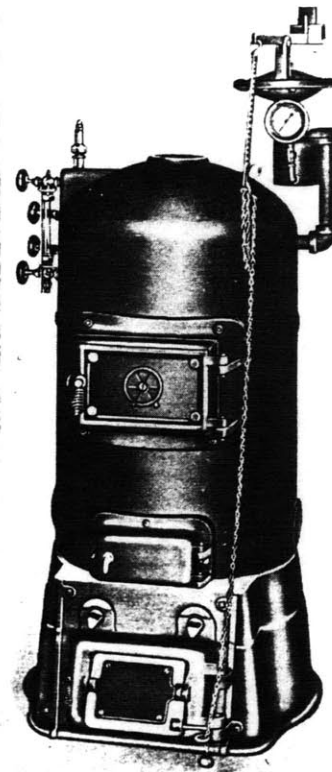


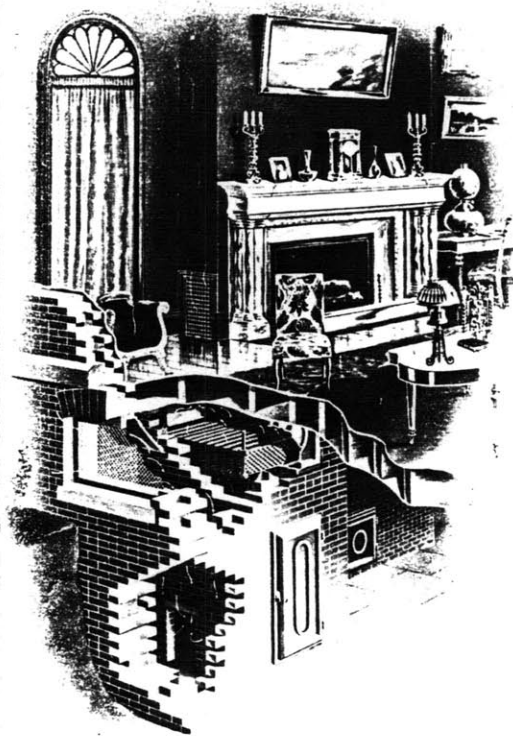
Fig. 84: The Menlo boiler, popular in small residences.

There was also a multitude of smaller firms, many of which began to consolidate beginning 1892. One huge consolidation in 1899 left the American Radiator Company of Buffalo in control of about three quarters of the boiler and radiator products produced in the entire country.¹⁵

INDIRECT STEAM AND HOT WATER HEATING

An indirect steam or hot water heating system such as those sold by H.B. Smith was similar in its basic appearance to the hot air furnace system, except that the furnace with its integrated radiator was replaced by a boiler with a large radiator or steam chamber mounted above it (see Fig. 86). In this form the indirect system suffered from many of the same deficiencies as hot air systems. Its principal advantage seems to have been its ability to additionally heat remote rooms by direct radiation using a single heat source, since the balance between direct and indirect radiation was easier to control than in the "combination" system mentioned in Chapter VIII.

A variation on the indirect system that offered far greater advantages was that in which an indirect radiator was placed in each of the rooms to be heated and supplied with hot water or steam (the latter more common) from the boiler in the basement. In this case each indirect radiator had its own fresh air intake duct in the exterior wall of the house (often the radiator was mounted below the floor, with the hot air register placed in the floor or baseboard). The advantages of this system were that each room had a separate source of heat, free of dust or obnoxious gases, and the system was not affected by winds. It also eliminated the long air ducts necessary with hot air systems and allowed the boiler to be placed anywhere in the basement.



Charm and comfort as pictured
by H. B. Smith Company
in the gay nineties

Fig. 86: Note the indirect steam
radiators mounted above the boiler.

Actually the term "radiator" is a misnomer, as the indirect radiator heated entirely by convection. Except for the fact that it drew its air supply from outside its operation was essentially the same as that of a standard convection unit such as that illustrated in Fig. 100. The modern independently-controlled room heating/cooling unit supplied with heated and chilled water from a central plant, such as is often used in commercial and institutional buildings today, is a direct descendant of these early indirect radiators.¹⁶

DIRECT STEAM HEATING

Steam systems can be divided into two categories according to the method of piping used. The simplest, and earliest to come into general use, is the one-pipe system. Water is converted in the boiler to steam, which rises first to the steam header (the tube atop the boiler in Figs. 79 - 81) and then through the risers to the radiators. There it condenses, thereby heating the room, and returns to the boiler as water through the same supply pipes. The piping had to be carefully laid out so that the water always ran back to the boiler; the knocking one so often hears in these old systems is the result of steam encountering a waterlock in the pipes or in a radiator.

The two-pipe system, which dates back to Count Rumford's Royal Institution of 1801, cost more to install than a one-pipe system (since it had twice as much piping) but gave superior results. The operation was essentially the same as in a one-pipe installation except that the condensate was returned to the boiler in the second pipe, affording quieter and more efficient operation.

Though from a standpoint of ventilation steam heating was not as desirable as a hot air system, it offered several mechanical advantages.

The radiator was easily adapted to almost any location in a room and its operation was not affected by winds. The circulation through the system was positive (being under pressure) and a distant room could be heated as easily as one close to the boiler. Early steam systems presented some problems in terms of controlling the heat supply. The radiators had to be large enough to heat the room on the coldest days and thus gave off too much heat for average conditions. Since the entire radiator surface was heated to a high temperature when the radiator was turned on, much manipulation of the valves was required to keep the room at a comfortable temperature. This problem was eliminated with the introduction of the so-called "vapor" system shortly before World War I. This system used two pipes and operated at close to atmospheric pressure. The steam supply to each radiator could be controlled easily at the inlet valve, which was placed at the top of the radiator (hot water radiators, with the sections connected at both top and bottom, were used). A special pressure-sensitive outlet valve maintained pressure in the system, allowing condensed water but not steam to escape from the radiator. Vapor systems were widely manufactured and advertised during the 1920's and '30's.¹⁷

DIRECT HOT WATER HEATING

The basic components of a hot water system were essentially the same as those in a two-pipe steam system, except that different radiators (with the sections connected at top and bottom) must be used and of course that the system operated at a lower temperature. Hot water systems were preferable to steam systems because the temperature of the radiating surfaces could be easily controlled (by adjusting the amount of hot water admitted to the radiator at the valve) and could be anywhere from room temperature to the operating temperature of the boiler, which was usually not above 180°. The safety hazard posed by very hot steam radiators was thus avoided. Another advantage was that the radiator's lower temperature caused more heat to be given off by

convection and less by radiation, thereby tending to keep the room at a more uniform temperature. (Hot water radiators gradually evolved into the pure convectors used today, as will be discussed later in this chapter.)

The only major disadvantage in hot water systems early in the century was that the circulation in the system was produced only by the difference in weight between the water in the hot leg of the system and that in the cold leg. Since this temperature difference was small, generally only 10° to 20° , the resulting force producing circulation was likewise small. This mandated careful design of the piping to reduce any undue friction in the pipes. The height of the system was also important, for the greater the height the greater would be the force reducing circulation.¹⁸ For this reason hot water systems were usually unsuitable for one-story houses or houses without basements. Fig. 87 illustrates one suggestion for getting around this problem. The hot water rises first to the supply tank elevated above the boiler and hence downward to the radiators.¹⁹

All of these disadvantages were overcome when a pump was used to circulate the water through the system. Before World War I such pumps were only used on hot water systems in large buildings in which the force of gravity was not sufficient to overcome the friction in the pipes. For a time engineers faced problems designing a small circulating pump that could stand up in service without leaking, but in the late 1930's this problem was overcome and the small centrifugal circulating pump began to appear on residential systems. Able to start and stop the flow of water at will, the thermostatically controlled pump allowed the heating system to respond quickly and efficiently to sudden changes in the heating load. Coupled with the automatically fired boilers that were beginning to dominate the home heating market, they spelled the end of the gravity hot water system.

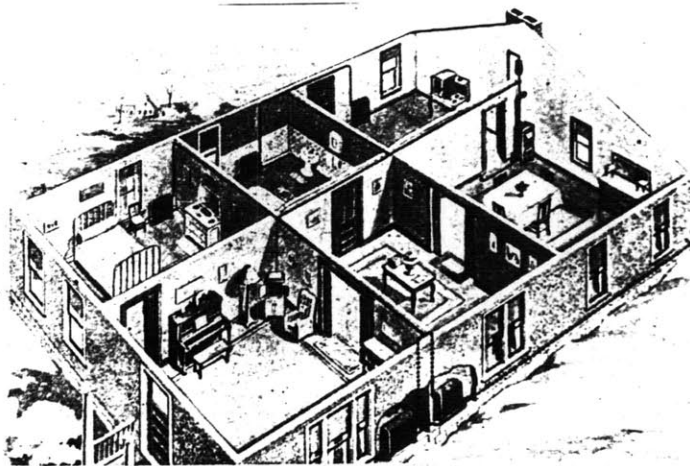


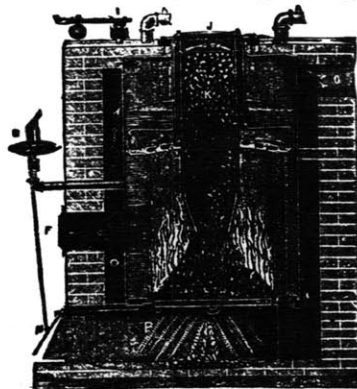
Fig. 87: Method of providing gravity hot water heating in a basementless house.

THE DUNNING BOILER,

PATENT, WROUGHT IRON OR STEEL.

OVER 5,000 IN USE.

Dampers Regulated and Coal Supplied Automatically.
With Self-feeding Coal Magazine,



SECTIONAL VIEW.

DESCRIPTION OF CUT.—I. Safety Valve; J. Magazine Cover;
K. Coal Magazine, showing gas-holes at top; M. Damper
Door; O. Smoke-exit; P. Ash Pit; R. Fire Box;
S. Steam Space.

IS THE OLDEST AND BEST
FOR
**Low Pressure
Steam Heating,**
And Insures a Warm House,
Day and Night.

MADE AS FOLLOWS:

As a **MAGAZINE BOILER**,
which requires attention
but once in 24 hours.
As a **SURFACE BURNER**, to
burn hard or soft coal,
wood or coke.
As a **HOT WATER BOILER**,
for greenhouse and hot
water heating.
As a **PORTABLE BOILER**, to
be set without brick work.
Also in two SECTIONS, to
pass through any door where
a larger one cannot be used.
And, in addition to the
above, we have under way
an entirely new construc-
tion of boiler, which will
excel anything yet upon the
market.

Send for Illustrated Cata-
logue with full description
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Agents Wanted.

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Send for Illustrated Catalogue with full description and Price List.

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Also Steam Engines and Boilers of all kinds and Machinery Generally.

Fig. 88: Magazine feed boiler.

The forced hot water method of heating likewise forecast the demise of the use of steam for heating private residences. The comfort and convenience of the new apparatus was augmented by the availability of modern, unobtrusive radiators and convector units designed primarily for hot water that found greater favor with decorators than the old style steam radiator that people had been trying to hide for years.

OPERATION AND CONTROL OF THE BOILER

Before the advent of automatic firing devices during the 1920's the operation of the coal-fired boiler was essentially the same as that of the hot air furnace in terms of the attention demanded of the householder. However, in addition to clearing and banking the fire, adding coal and setting the drafts it was necessary to check the water level in the boiler and in a steam system to periodically drain sediment from the blow-off valve located below the water level indicator.

A variation on the standard boiler that was offered by a few manufacturers is illustrated in Fig. 88. This magazine feed boiler supplied coal to the fire automatically from a top-loading cylinder located within the boiler. The coal supply needed to be replenished only once a day with this arrangement. Filling the magazine, however, must have been a chore, since it had to be loaded from the top of the boiler.

In addition to the draft and damper controls, which were usually connected to a thermostat as on a furnace, there were several other regulating devices on a typical boiler, all of which can be traced back to the Stephen Gold boiler of 1856 (see page 108 and Fig. 77). The most common such device was a rubber diaphragm (Fig. 89) which controlled the steam pressure (in a hot water boiler, the water temperature) by

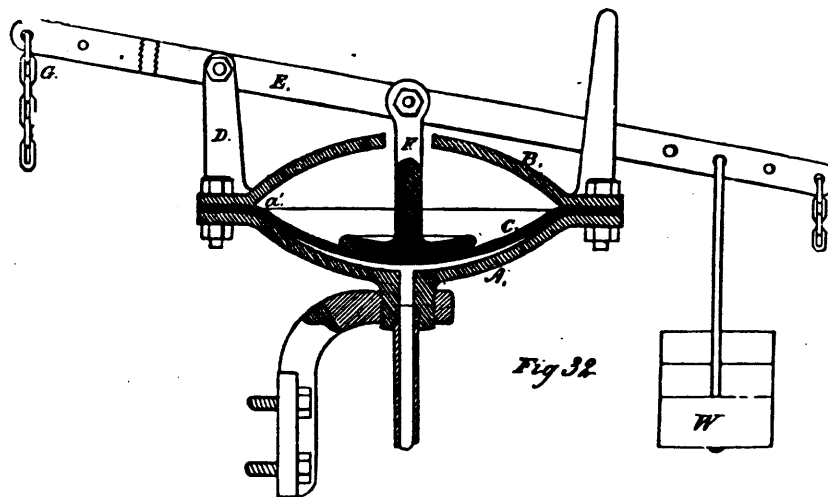


Fig. 89: Diaphragm control used to regulate operation of the boiler.

operating the drafts on the ashpit and fire doors, the safety valve and a "break draft" damper in the chimney. The operation of the diaphragm, connected from its bottom to the water in the boiler, was simple: changes in the water or steam pressure in the boiler would cause the diaphragm (C) to rise or fall, thereby moving the piston (F) and the lever arm (E). This was connected by chains (G) to the appropriate draft doors which would be adjusted as the situation demanded. Another control found on the better grades of boilers was an automatic water feed, operated by a float valve similar to that in a toilet tank.²⁰

RADIATORS

The evolution of radiator design stems from two basic types. These are the flat sheet iron box or mattress type of James Watt and Stephen Gold (Fig. 90), and the coil of wrought iron pipes of Angier Perkins that was introduced to the United States by Walworth & Nason.

The mattress type evolved into Gold's Pin Radiator, which utilized a cored iron casting with an extended surface of "pins" to increase the area available for heat transfer to the air. It proved very efficient when used in clusters for indirect heating, but, since it heated by convection rather than by radiation, it was a quite inefficient design when used for direct heating, as in the Whittier radiator of 1868 (Fig. 91) a cast-iron horizontal bar-type with fins to extend the surface area. H.B. Smith began selling the Whittier in 1870 and by 1876 owned the patent rights to it. A Mills-invented variation, introduced the following year, was more efficient but still was not good enough to compete with the column type radiators that were beginning to appear.²¹

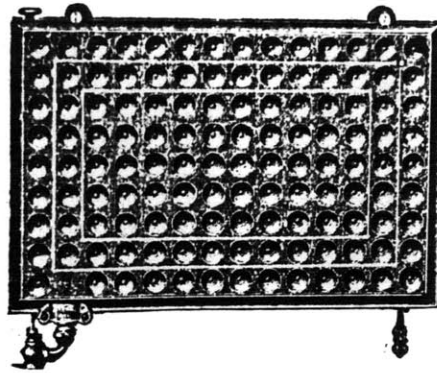
Nason designed a radiator (Fig. 92) in which tubes, closed at their upper ends, were threaded into a cast-iron base. This radiator later appeared with two, three and four rows of columns covered with an

an ornamental top. The handwork involved made these radiators expensive to build.

The use of return bends at the upper ends of the pipes of the radiator is believed to have been invented around 1860 by a Miles Greenwood. N.J. Bundy used this loop principle in what was probably the first cast-iron sectional radiator (Fig. 93). The loop was cast as a single piece, the two tubes joining together above the base and screwed into it by a single threaded connection. Less elegant pipe radiators appeared in an incredible variety of forms in attempts to gain the greatest heat output (Fig. 94).

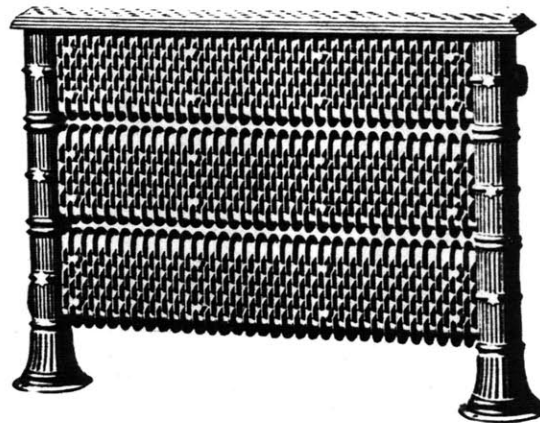
John H. Mills had discovered that cylindrical pipes were not the best shape for efficient results when grouped to form radiators and designed what he called a Gothic tube, the section of which resembled the pointed quatrefoil of Gothic architecture. In the famous Reed radiator of 1878 (Fig. 95) similarly shaped Gothic tubes were used, cast in sections of two pipes each with a return bend at the upper end. The lower ends were connected to the base by the use of a soft metal, forming ferrules into which the ends of the loop were forced under pressure. The Reed radiator's combination of economical manufacture and efficient radiation was superb. This was the radiator used with the Mills boiler for direct heating by steam.

The Union radiator (Fig. 96) was developed in 1896 by John R. Reed to meet the demand for a good direct radiator for use in low pressure hot water systems, which were becoming more popular for heating dwellings. Made of three-pipe sections, a larger elliptical column flanked by two smaller tubes, the Union was revolutionary in that it did away with the need for a separate base. The sections were joined at the top and bottom by taper nipples of soft iron, pressed together by special machinery. The end sections incorporated the feet on which the radiator stood. The construction method gave the Union an



Known popularly as the "mattress type" radiator, this flat box of sheet iron was first patented in the United States by Stephen J. Gold of Cornwall, Connecticut, in 1854. It resembled closely an experimental model invented and built by James Watt in England in 1784. It was never manufactured by H. B. Smith & Co.

Fig. 90.



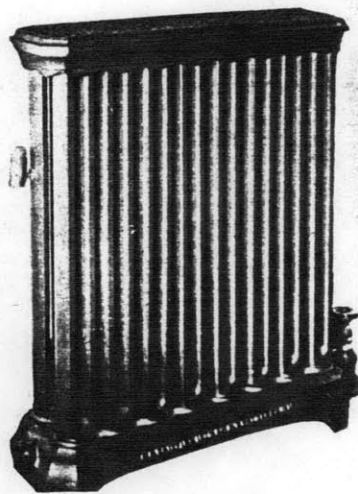
In a further development of this flat box for the condensation of steam, this bar type radiator, the Whittier, added fins to increase the heating surface and was made of cast iron. Patented by Charles Whittier of Boston in 1868, it was manufactured solely by the H. B. Smith Company after 1876.

Fig. 91.



Pipe radiators, a standard type for more than half a century, evolved from this model, invented by Joseph Nason, and manufactured by Nason in New York and by the Walworth Company in Boston before 1860. Tubes of wrought iron, closed at the upper ends, were threaded into a cast iron base.

Fig. 92.



The Bundy radiator substituted cast iron tubes for the earlier pipes of wrought iron. Cast in pairs, with return bends at the upper ends, these were likewise joined at the lower ends, in order to be threaded in pairs into the base. Patented in 1874, it was manufactured by the A. A. Griffing Iron Company of New York.

Fig. 93.

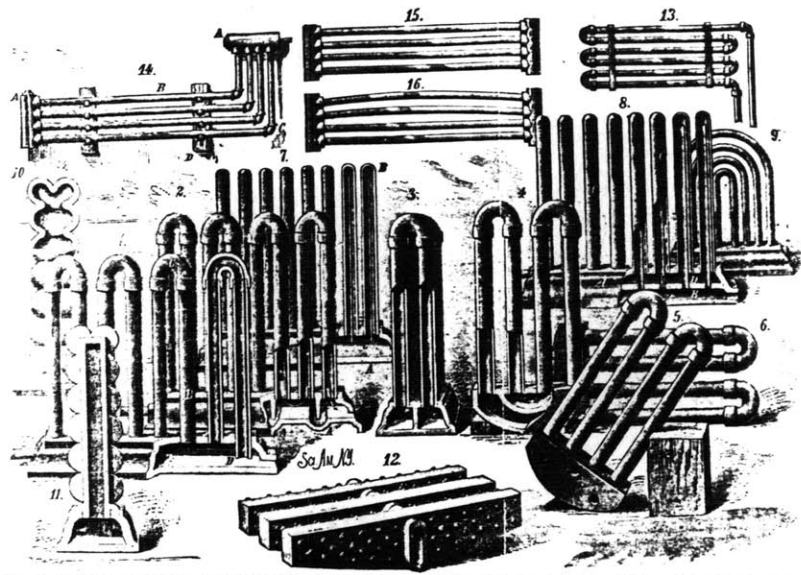
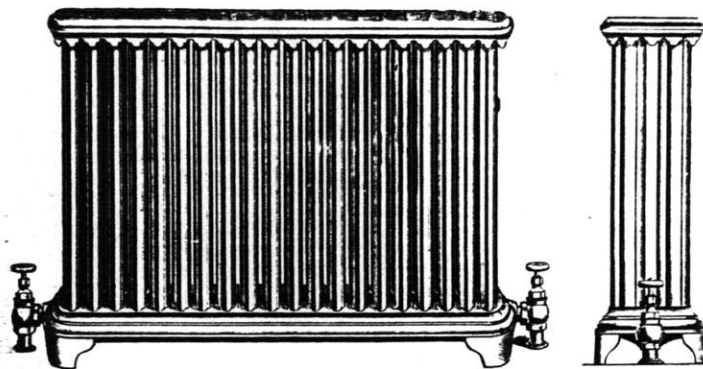
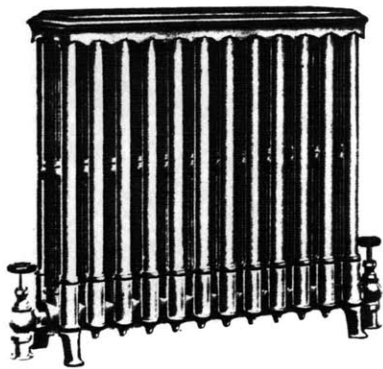


Fig. 94: Pipe radiators appeared in a great variety of designs to suit every purpose.



A revolutionary development appeared in the Reed radiator, patented by J. R. Reed in 1878, and manufactured by the H. B. Smith Company. For the first time a tube radiator was designed which did away with the slow and expensive process of threading tubes into a base. They were joined to the base by the use of a soft metal, forming ferrules into which the ends of the pipes were forced by pressure.

Fig. 95.



The Union radiator of the H. B. Smith Company was even more revolutionary than its predecessor in that it did away completely with the need for a base. Patented in 1886, it was made up of sections joined to each other at top and bottom, while the end sections acted as supports. This method was later adopted throughout the industry and was never altered basically.

Fig. 96.



Fig. 97: The "Imperial" dining room radiator of the Gay 90's, complete with built-in warming oven.

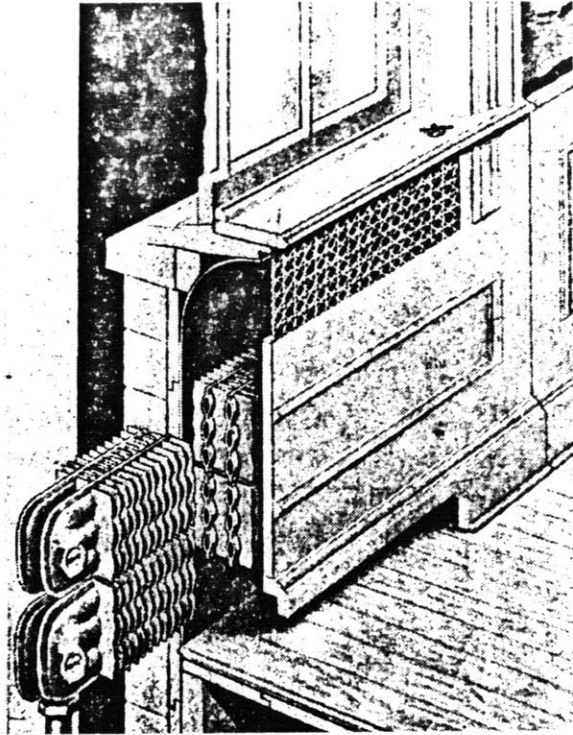


Fig. 98: Enclosed extended-surface radiators were really convectors.

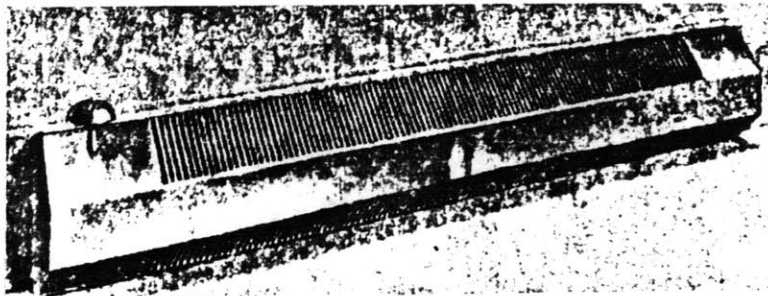


Fig. 99: Baseboard convector of the late 1930's.

advantage over its chief rival, the Bundy, itself redesigned for hot water but retaining a separate base, and this radiator, coupled with the Mills boiler, put the H.B. Smith company among the leaders in direct hot-water heating as well as steam.

Until a further revolution in radiator design in the 1920's there was no fundamental change in manufactured models. The sectional design of the Union became accepted as standard; numerous examples can be found in service in older buildings today. During the gay 90's radiators came to be regarded as ornamental pieces and their decoration became increasingly elaborate. The "Imperial" model pictured in Fig. 97 was designed for use in the dining room and featured a built-in warming oven. The trend toward ornamentation soon faded and later radiators of the type were plain and dignified.²² During the 1920's and later radiators were distinctly out of favor with decorators, and numerous articles appeared in popular magazines suggesting ways that radiators might be hidden or covered with grillwork (unfortunately, usually to the detriment of their heating performance).

Conventional radiators such as those discussed above actually heated mostly by convection, with only about 10 to 30% of the heat supplied by radiation. However, they were not particularly designed to facilitate the maximum airflow that would be desired in a convective unit. During the late 1920's engineers began to develop new designs that were better related to the way "radiators" actually function.

The "Fantom" radiator, manufactured by the American Radiator Corporation, was made of cast iron but presented a nearly flat, continuous front to the room to increase the radiating surface. The inner part, which varied in depth according to the capacity required, was arranged to allow freer air flow and more surface area for convective heating. The air outlet at the top would be either vertically through grills in the window sill (some models were designed as an integral part of a steel window unit) or would divert the air flow horizontally into the

room, thus helping to prevent the heated air from rising directly to the ceiling.

Radiators of the extended surface type (Fig. 98) were usually made of non-ferrous metals such as brass or aluminum alloys. These were designed entirely as convectors and made no special effort to utilize radiated heat. With their finned surfaces the elements of these radiators bear a marked resemblance to the Whittier radiator of 1868. Placed in an enclosure which served to direct the air current, their appearance was quite unobtrusive.

A further development along the same lines was the base board radiator (Fig. 99), which is essentially similar to the baseboard convector commonly used with residential hot water heating systems today. The linear configuration of these served to distribute the heat more evenly throughout the room.²³

CHAPTER X

NEW FUELS AND AUTOMATIC HEAT

A series of events beginning during the peak of America's war effort and continuing through the period between the wars combined to cause revolutionary changes in American home heating practices. Public uncertainty about the ready availability of an ample coal supply greatly stimulated the development of oil and gas as heating fuels that was already underway. Greatly improved oil and gas burning equipment, offering the superior comfort and convenience of completely automatic heating, captured the attention of a fuel conscious public, dealing the once-mighty coal industry a mortal blow. Belated attempts by coal producers to develop new hardware to compete with the newer fuels had technical success but failed to recapture the market, and by the 1950's coal had virtually passed from the scene as a home heating fuel.

THE ABDICATION OF KING COAL

The early development of the coal industry and its rise to pre-eminence was chronicled in Chapter VI. In 1913 the estimated United States coal reserve, including only coal above a 3000 foot depth, was 3.5 trillion tons. Through the close of 1911 only 14.2 billion tons had been exhausted and annual production was running at 500 million tons. R.H. Byrd wrote in Scientific American, "It may seem that a genuine 'coal pinch' for the American nation is a far distant contingency" and "undoubtedly the oil supply will go first."¹

In a sense Byrd was right, for the shortages that occurred just five years later were not the result of a lack of coal but rather were

the product of a breakdown in the system of supplying and distributing the fuel. The problems affected primarily the anthracite industry, which supplied most of the coal used for domestic heating, among other uses. The crisis became especially acute during the winter of 1917-18, when local shortages of coal became widespread, leaving homeowners, industries and even the War Department faced with rising prices and occasionally empty coal bins. The peak occurred in January of 1918 when the Fuel Administration ordered an eight day industrial shutdown in 28 states to allow coal supplies to be diverted to urgent war needs (war supply ships had been unable to leave port for lack of coal), an action that generated considerable controversy.²

A number of factors contributed to the crisis. One cause seems to have been the virtual breakdown of the nation's railroad system, the principal carrier of coal. Coal comprised half of the roads' freight loads, and a shortage of coal cars, engines and other facilities prevented movement of the fuel.³ This shortage was perhaps less in numbers than it was in management. Inept management of the railroads caused shipments to be tied up in yards for weeks, resulting in virtual paralysis and finally a two-year government takeover of the system.

Another factor in the "coal famine" was an apparent shortage of skilled and semi-skilled mine labor due to the military draft, an example of conflicting policies on the part of the federal government. In 1917 the labor force in the mines had declined 14% from the level of the previous year, in the face of increased demand.⁴

As might be expected, the coal shortage brought charges of profiteering by the coal operators. It was reported that profits of some bituminous operators in 1917 ran as high as 2000% over the value of their capital investment. The operators countered by claiming that their

profit was only 16¢ a ton on coal they sold for \$2.61, and that the high profits cited were for a few small mines having little invested capital that operated only during the famine.⁵ There were also charges that some operators diluted their coal with incombustibles during the famine.

The crisis, both in its causes (aberrations in normal supply and inept government policy) and in its immediate effects (shortages and rapid price increases), was very similar to the oil crisis that gripped the nation in 1973-74.

The coal shortage of 1917-18 had a few immediate results. It focused attention on oil and gas as heating fuels, especially among the wealthy who could afford to pay more to be assured of an uninterrupted fuel supply. It brought a degree of public awareness of the need for careful furnace firing and maintenance to cut fuel waste, and to the performance of the building envelope as a contributor to heat loss. Weatherstripping and building insulation began to attain acceptance as their cost effectiveness was shown. Their use became virtually mandatory when oil or gas was used for fuel.

Had the coal supply returned to a state of normalcy and stability after the war the ensuing decline of the industry might have been averted, for conversion to other fuels had been limited to a few wealthy individuals. Most of the public had gotten by with conservation efforts, some cold nights and the help of small gas burning radiators and kerosene stoves. However, coal strikes in 1919 and the early 20's aggravated public uncertainty about the coal supply, even though a great deal of coal was mined by non-union workers during the strikes. In 1920 prices for bituminous rose to \$9 to \$15 a ton, though by threatening to regulate the industry the government succeeded in getting the price rolled back to between \$3 and \$5 a ton.⁶ The continuing instability of the labor

situation in the coalfields throughout the 20's and 30's prevented the industry from winning back public confidence, and the trend to new fuels was irrevocably underway.

GAS AS A HEATING FUEL

Two basic types of gas have been used for fuel in this country: manufactured gas and natural gas. Of the former there are several varieties which will be noted briefly: each saw use at one time or another in various parts of the country. The oldest and simplest form is "coal gas" -- the product of the distillation of soft coal over heat in a closed vessel. The process also yields coke and small quantities of tar, benzol and other substances.⁷ "Water gas" is made by alternately passing air and blasts of steam over incandescent coals. "Producer gas" is manufactured by a similar but continuous process using air and a small quantity of steam. "Oil gas" is manufactured from petroleum rather than coal and has nearly as high a heat value as natural gas. It was often used to enrich water gas, the result being known as "city gas."⁸

Coal gas was first produced accidentally about 1609 by one of the later alchemists, a Belgian named Van Helmont. No material progress was made in the application of this "mysterious spirit," as Van Helmont called it, until 1792, when William Murdoch, an engineer associated with James Watt, contrived to distill gas from coal and succeeded in lighting his house with it. Later he improved and enlarged his plant and provided lighting for Watt's factory. Then followed street lighting and the lighting of a few public buildings, first in Europe and then in this country. The cost of such lighting was high, however, so progress was slow though steady. Baltimore in 1817 was the first city in the United States to light its streets with gas and was the home of the first gas company.

Gas lighting did not attain widespread use in homes until the 1870's. Small home gas generators were available and used in areas where municipal gas service was not provided. The invention of the simpler and more brilliant electric light late in the nineteenth century heralded the eventual demise of gas lighting and threatened the existence of the gas industry, though the invention by Welsbach of the incandescent mantle briefly gave gas lighting a new impetus.

The perfection of the electric light forced gas companies to find and promote other markets for their product. Gas utilization was extended to cooking and water heating and, in the 1920's, to house heating, resulting in large increases in gas consumption, despite the total conversion to electric lighting (four times as much gas was used in 1928 as in 1908). The key development in the extension of gas to these other uses had been the invention of the Bunsen burner in 1855. Bunsen discovered that if gas were mixed with air before it was allowed to burn, the flame would be a clean blue with almost no odor, and would be much hotter. All gas burners used for heating today operate on this principle.⁹

The first gas heating plants, installed around the time of the coal famine, were mostly in the large houses of well-to-do people who could afford the expected added cost of using gas instead of coal. Since their owners were prepared to pay for the best, these systems usually incorporated the most advanced control devices available. One installation that attracted a good deal of attention was in the 17 room home of a New York bank president. The system had hot water radiators and a return tubular boiler (like the Mercer) fired with manufactured city gas supplied directly from the city mains.

Especially noteworthy were the system's sophisticated (for the time) temperature controls -- devices that were still considered the ultimate a decade later. A clock thermostat in the living room kept the house at 70° in the daytime and automatically cut back to 50° at night. A control on the riser leading from the boiler regulated the temperature of the water, keeping it at 120° in moderate weather and automatically increasing to 180° on the coldest days. The system was equipped with a pilot light, allowing it to cycle on and off as needed.¹⁰

After the system had been in service for a season it was estimated that it had actually cost less to operate than a similar coal-fired system would have; this perhaps being due to the sophistication of the controls. This result surprised heating engineers and even the owner, for manufactured city gas was generally considered unable to compete in cost with coal. The average fuel cost with the best equipment was usually estimated to be 25% higher with gas than coal.¹¹ In weighing potential fuel consumption of a heating system much attention had to be paid to the fuel value of the gas supplied and to the rate structure that was available to the homeowner.¹² Both of these factors varied widely from one locality to another.

Many states had laws requiring that city gas be supplied with a heat content of 500 to 600 BTU/cu. ft. This necessitated enriching the water gas (300 to 400 BTU/cu. ft.) with expensive, higher energy oil gas, thereby raising the price of the delivered product. One writer of the period argued that gas could be burned economically for heating at the lower prices allowed by the lower heat value of water gas and cited studies showing that users consumed the same quantity of gas whether it was enriched or not.¹³

Despite the increases in consumption the manufacture of city gas remained a fragmented, locally based industry, unable to achieve economies of scale. A study by Arthur D. Little in 1927 found that the smaller municipal gas companies were too often antiquated organizations lacking in vision. He argued that many communities would be better served if they were supplied with gas by high pressure transmission lines from large, centrally located gas plants, noting that natural gas was then being successfully piped as far as 300 miles.¹⁴

That sort of reorganization of the manufactured gas industry was not to take place, however, for in the following decade manufactured gas was to be replaced as a fuel in many parts of the country by natural gas, which had a higher heat content (1000 BTU/cu. ft.) and cost relatively little to produce. Natural gas, contained under pressure beneath the earth's crust in many parts of the country (it provides the pressure that forces oil to the surface when a well is drilled), had for years been flared off as a useless byproduct of oil drilling. As its value as a fuel became known, however, the wells were capped and pipelines built to supply the gas to nearby towns.

During the 1920's natural gas was so cheap in many places that towns in Ohio, Indiana and West Virginia, where early production and distribution was centered, found it more economical to let the street lights burn all day than to employ a lamplighter. The low prices persuaded many industries to convert their coal boilers to gas. The distribution system was not yet highly developed, though, and supply soon could not keep up with the burgeoning demand. At times pressure was barely adequate to supply household demand and many industries found their supply cut off and were forced to switch back to coal. Some experts advocated restricting natural gas to domestic uses and

having power plants use coal, which they could burn more efficiently than could the homeowner.¹⁵

During the early 1930's the natural gas distribution network underwent tremendous expansion. By 1930 capital investment in the natural gas industry was already over \$4 billion. At a time when general business activity was shriveling steel pipe plants were working around the clock to meet the demand for gas pipe. By 1931 the distribution network had extended to 33 of the 48 states.¹⁶ Interconnection of the supply network resulted in price reductions, bringing natural gas well within the range of practical fuels for home heating use.

In place where natural gas was available it offered several advantages over other forms of heating. Gas furnaces and boilers were, in 1930, probably the most efficient form of domestic fuel in terms of extracting the full heat value of the fuel. With the reductions in price, a properly insulated and weatherstripped house could be heated as economically with gas as with any other fuel. And, like oil burners, gas heating equipment of the time had the advantage of completely automatic operation. When installation costs were considered gas had a decided edge over oil, for owing to the cost of the necessary storage tank an oil burner installation alone cost more than an entire gas burner and boiler assembly.¹⁷

New Englanders, however, were unable for many years to share in the benefits of natural gas. Opposition by railroad, coal and manufactured gas interests prevented the spread of natural gas into many areas that it might otherwise have served.¹⁸ Boston, for instance, was not reached by a natural gas pipeline until 1953.¹⁹ The result was that New Englanders who wished to escape from the uncertainties of the coal situation and to enjoy the convenience of automatic heating had little choice but to convert to oil. Fig. 100 illustrates

Fig. 100: TYPES OF HEATING FUELS IN USE, 1970.

	Mass.	Northeast	North Central
Utility gas	28%	37.1%	66.8%
Fuel oil	66	54.4	19.6
Coal	0.4	3.5	3.3
Electricity	4	3.1	3.1
Bottle gas	1	1.1	6.3

Source: U.S. Census of Housing, 1970, V. 1, p.526 & V. 23, p.144.

the dependence of northeast U.S., and especially Massachusetts, on oil, in contrast to the situation in the midwest where natural gas was readily available at an early date and became the dominant heating fuel.

OIL AS A HEATING FUEL

The first oil well in the United States was that of Colonel E.A. Drake at Titusville, Pennsylvania, which came in on August 27, 1859. Production of oil increased dramatically, from 2000 barrels in that year to 500,000 the following. Supply so greatly exceeded demand that the price of oil dropped in three years from \$20 a barrel to 10¢; by 1879 the U.S. was shipping 8.5 million barrels a year to Europe.

Despite these surplusses there was a hesitancy to adopt oil as fuel that was apparently due in part to uncertainty as to the extent of the supply. Major discoveries in Texas and California helped to encourage major energy users to convert to oil.²⁰

A more significant hindrance to the adoption of oil as a fuel had been the difficulty encountered in burning it in its raw state. What was normally considered fuel oil was the thick, unrefined product from the wellhead or the residue left after lighter products were refined off; neither of these could be easily piped or injected into a firebox. Until 1885 most experiments dealt with finding ways to convert oil to a gas, but these were unsuccessful. The method that was finally adopted was one used extensively on the Tsaritzin Railway in Russia, which used a jet of steam to vaporize the oil, supplied under pressure, and inject it into the firebox as a mist.²¹ By the end of the first decade of this century improved technology, increasing supplies of oil and higher prices for coal had combined to bring to oil a high degree of acceptance as a fuel for large plants. Its greater efficiency, economy, cleanliness and ease of handling were widely recognized among

fuel experts. Automatic controls for oil and air supply and draft regulation were replacing the methods of hand operation that had cut the efficiency of large plants.²²

The situation at the end of World War I gave no indication that oil was about to become a major source of home heating energy. There was still a substantial amount of skepticism about the future price and availability of oil, the reserve of which was variously estimated as 10 to 30 years.²³ The heavier industrial grade fuel oils were unsuited for home use as their burners required high pressure steam to heat the oil and vaporize it; such an arrangement was not feasible in the home. Lighter oils suitable for use with the domestic oil burners that were available varied widely in viscosity and quality. The only fuel of uniform quality available to the householder was kerosene. Many oil companies would supply 2 or 3 grades of oil at varying prices; the differing qualities and names for grades of oil resulted in much confusion. It was not until 1927 that fuel oil grades were standardized and that a distilled, lighter grade was refined specifically as a home heating fuel. A further deterrent was the price of the equipment: in 1923 the cost of installing an oil burner and storage tank on an existing furnace or boiler in a typical house was between \$350 and \$700 or even more. Safety was also a concern, since oil is more flammable than coal, but in 1924 more fires started from putting hot coal ashes into barrels than from all oil burners installations.²⁴

Nevertheless, for those who were determined to escape the tyranny of the coal furnace during the early 1920's there was really no choice. Natural gas was yet to be made available and many localities did not manufacture gas service. And oil heating was known to be less expensive than coal. The rush to oil was on, and the name of one of the first oil burners, "No. 1," symbolized the attitude. In 1921

there were only 21,500 domestic oil burners in service in the country. The repeated coal strikes hastened the switch to oil, especially in Chicago and New England. The 1926 coal strike increased the total number of burners in service to 221,000 - ten times what it had been just five years earlier.²⁵

There were two basic types of oil burner on the market in the mid-1920's. One was the gravity type, which cost less to buy but suffered from sooting and inefficient combustion since the draft was not controlled automatically. It was not highly recommended. The other type was the atomizing burner (Figs. 101 and 102), which with refinements is the type universally in use today. In these the oil is drawn from the tank by a pump, forced through a nozzle under pressure, mixed with air and ignited with a gas pilot or an electric spark. The rate of feed was controlled by the air pressure and the size of the nozzle opening. Operation of the burner was controlled by a thermostat in the house. Since the burner controlled the oil and air mixture there was no need to adjust the drafts; perfect combustion was automatic.

The boom in the market for oil burners brought a flood of devices for converting coal burning plants to oil; such conversion made up 80 to 90% of the market throughout the period between the wars. The boom in sales put marketing far in advance of engineering, causing service complaints to multiply. People apparently felt that the convenience overshadowed the occasional problems, for sales continued to rise through the twenties, reaching a peak of 131,000 units in 1929.

A slackening of sales during the depression gave engineering and manufacturing quality a chance to catch up and restore some balance to the industry. With drops in oil prices and a slowing of natural gas pipeline extension in 1931, the oil burner industry, already the most widely used form of automatic heating, geared up for a major

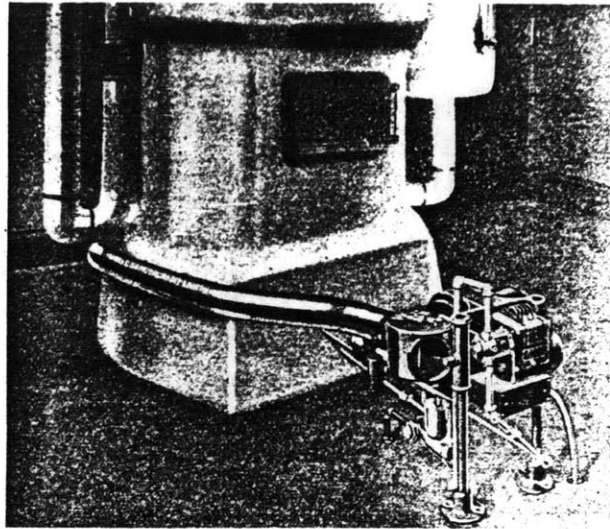


Fig. 101: An early oil burner in place. Its name, "NoKoi," symbolized the attitude that made oil burners so popular.

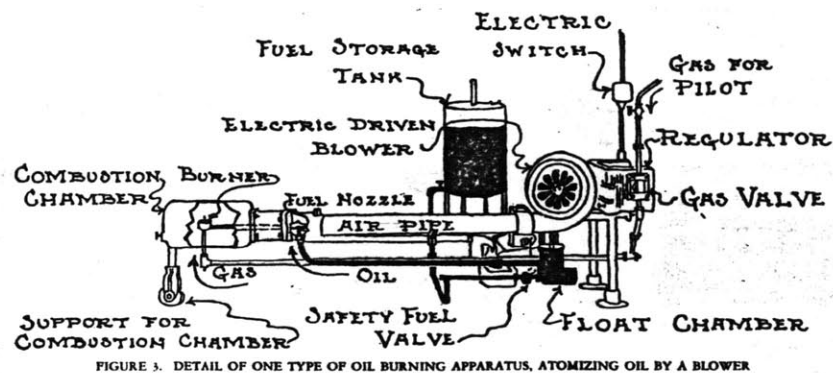


Fig. 102: Major components of the early oil burners.

sales push.²⁶ By 1935 sales were moving close to the 200,000 mark annually; 90% of these were underexisting boiler units.

At the beginning of the 30's boilers and furnaces began to be re-designed specifically for oil burning. A newcomer to the market was the combination burner-boiler unit. One such new product that was revolutionary in appearance and design was introduced by General Electric in 1932 -- its first venture in home heating (Fig. 103). It featured a top-fired, down-draft, counterflow combustion unit with the combustion spaces completely surrounded by the boiler water. The unit could be applied directly to steam systems or, with the addition of a water circulating pump for fast response, to hot water systems. A smaller version was also produced, aimed at smaller homes in the lower income ranges.²⁷

Such combination units do not appear to have caught on, for most units on the market today, though designed specifically for oil, are designed as furnaces or boilers to which the oil burner is added when the unit is installed. This allows greater flexibility in selecting or replacing the burner. The significance of models such as the G.E. lies in their effort to transform heating apparatus from ugly mechanical devices into attractive appliances. The freeing of the space that had been taken up by the large furnace and coal bin had changed people's attitudes toward basements, which now came to be used as part of the living space of the house. Heating advertisements of the 30's and 40's often showed shining, attractively styled furnaces as a part of the basement "family" room, with happy children and a relaxed parent (who no longer had to shovel coal into the fire) nearby.

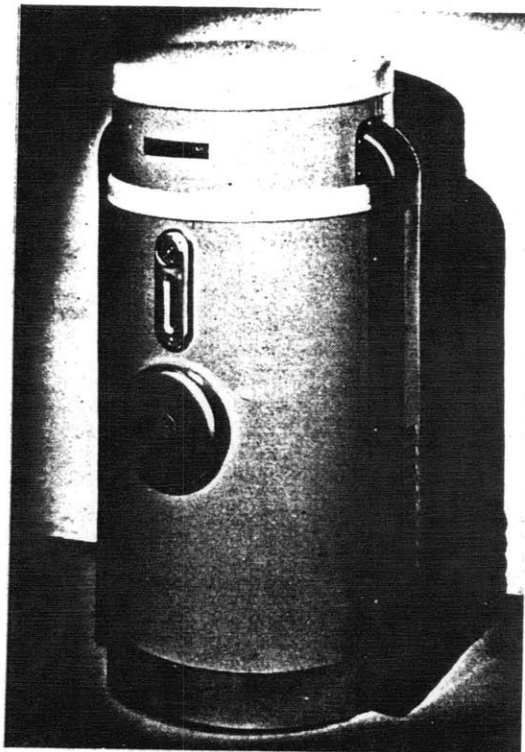


Fig. 103: General Electric oil furnace. The boiler unit was similar in appearance.

COAL ATTEMPTS A COMEBACK

In an attempt to counter the inroads on the coal market being made by oil and gas (anthracite sales had fallen 25% from 1926 to 1931)²⁸ the coal industry began promoting the use of stokers starting around 1929. These were basically screw-type mechanical devices that automatically fed coal into the firebox. They were thermostatically controlled to provide even heating and allowed the furnace to burn the cheaper sizes of coal efficiently. Some stokers would convey the coal directly from the coal bin to the firebox (Fig. 104), others had a hopper that required hand filling once every two or three days in mild weather and 10 minutes daily attention in cold weather. Some stokers also had a provision for automatically removing the ashes.

Stoker sales started off slowly, increasing to slightly over 4000 units in 1931.²⁹ In the eastern part of the country stokers were most popular at first in New York, New Jersey and Massachusetts.³⁰ To counter the convenience of oil and gas some coal dealers offered a contract heating plan in which the dealer would install a stoker in the home, supply a man to fill it and remove the ashes when needed. The homeowner would simply set the thermostat and pay a flat rate per ton of coal used or per season. The first company to adopt this practice was the Horn Coal Co. of Lowell, Mass., with 80 customers buying service on a flat per-ton basis.³¹

Sales continued to rise dramatically, to 48,000 units in 1935, but this was far below the pace of oil burner sales, and public awareness of stokers remained low. At a stoker show in St. Louis many citizens came in to ask "what those machines" were, having never seen a stoker. Stokers had other problems, too. Most of them still required some amount of attention and so did not offer the same degree of completely automatic

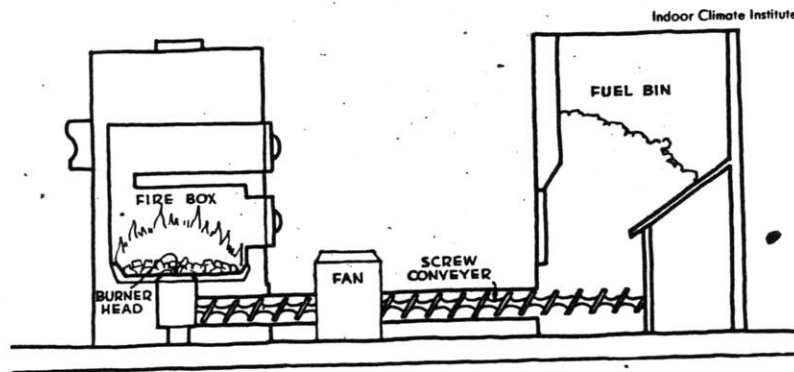


Fig. 104: Diagram of a stoker that automatically drew the coal from the fuel bin. The fan provided a forced draft in the firebox.

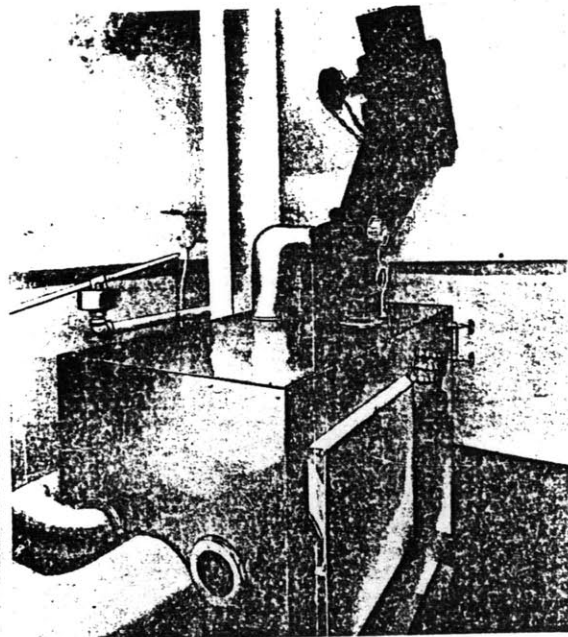


Fig. 105: The Philadelphia and Reading Coal and Iron Company's completely automatic coal furnace.

heating as did oil or gas. Furthermore, the cost of conversion was not cheap in the mid 30's, averaging between \$300 and \$600, at a time when oil burners were going for under \$300.³² Stokers sold well in the midwest and elsewhere but like the earliest oil burners were hurt by design deficiencies in many models, the rapid expansion of the industry and the extravagant claims of some manufacturers.³³

By 1938 public acceptance of stokers was increasing, enough so that some major firms, including General Electric and Westinghouse, had placed stoker/boiler units on the market.³⁴ Sales were up to 93,000 or one for every 2.2 oil burners sold, and 11% of stoker sales were to replace oil burners. At this time the automatic heating situation looked liked this: 1,555,000 homes were heated with oil; 720,000 were heated with gas; 300,000 were fueled with stokers.³⁵

Though stoker sales continued to mount, they were unable to match the pace of oil burner sales, which were almost entirely at the expense of coal, and coal's position as a home heating fuel continued to deteriorate.

Stokers were not the only innovation that the coal industry came up with during the 1930's, though they were the only commercially successful one. The Parco Maxmatic Furnace (Fig. 105), built by the Philadelphia and Reading Coal and Iron Co. in 1933, was a completely automatic furnace that fed coal from a bin, removed its own ashes, tended its own drafts and shook its own grates, all automatically. It used an extremely efficient steam boiler featuring a very long gas travel. The furnace was capable of providing heating and cooling, humidity control, domestic hot water, ice water in the summer, and would run the refrigerator and the clothes dryer, using less coal in a year for all these tasks than formerly was required to supply the average house with heat and hot water alone. Despite these impressive features, there is no evidence that it was a great success commercially.

Despite the development of such sophisticated hardware as that described above, coal gradually faded away as a significant fuel for residential heating. Why? Part of the answer lies in the nature of the fuel itself. Coal is bulky and dirty. The coal bin took up a substantial amount of room in the house, and some amount of dust escaping was inevitable (by contrast, oil storage tanks were usually required to be buried outdoors). While coal was still relatively inexpensive it had the disadvantage of requiring that the fire be maintained at all times. Automatically ignited fuels offered the economy of not being burned when heat was not being called for. On top of these deficiencies, coal had, one could argue, a bad image. Years of labor dispute had eroded public confidence in the ability of the coal industry to keep it supplied. And years of shoveling coal into the furnace had given people an unfavorable impression of coal that were not easily shaken.

INSULATING THE HOUSE

The advent of oil and gas as heating fuels brought a new awareness of the contributions of the building envelope to heat loss and the value of adequate insulation, and the use of insulation in dwellings became increasingly common.

In Chapter II it was shown how the wattle-and-daub infill that formed the exterior walls of the first houses at first remained after the walls were covered with clapboards. Gradually the practice of filling in the wall cavity with this material or with another such as straw fell from favor, perhaps being regarded as unnecessary.

Balloon framing, introduced in the 1840's and the most common form of residential construction well into the twentieth century, further eroded the thermal performance of the walls. In that form of framing the studs are run continuously from the base of the house to the roof.

This practice would leave a continuous air shaft between the studs running the entire height of the house. If not blocked off, that built-in "stack" would allow heat to be carried up the walls to the attic where it would then escape through the uninsulated roof.

The period around the end of the nineteenth century appears to have been one of great advancement in the understanding of the thermal performance of buildings. Heating texts of the late 1800's deal with such topics as calculating heat losses and estimating required furnace capacity generally by approximations and rules of thumb. Furnace capacity was often specified in terms of the cubic volume that the unit could heat without regard to the shape or nature of the building envelope. By 1915 a systematic study of the thermal properties of structural materials was being carried out by various government bureaus and a number of technical societies.³⁶ These results soon began to appear in heating texts.

During the twenties the greatest advocates of insulation were those promoting gas and oil heating, which were still more expensive fuels on a cost-per-BTU basis than was coal. There were other advocates, too; some of them more able to influence the course of events. Many New York bond and mortgage companies would not give the full loan value of an un-insulated building.³⁷

With studies done in the late 1920's indicating that a 60% fuel saving could be achieved by using one inch of insulation and storm windows on the house a number of different types of insulation began to appear on the market. One of the most common types of insulation was $\frac{1}{2}$ inch thick insulating board, made of cork or wood fibers (celotex), which was usually used in place of the conventional wood lath or exterior sheathing or both. Eel grass, woven into a thick elastic cushion, also found favor as an

insulating material. Another widely used product was hair insulation, consisting of a heavy layer of thoroughly cleaned cattle hair securely fastened between two sheets of protective paper. This was commonly applied over the exterior wall sheathing, held in place with battens, and covered over with the finish siding. Paper-backed rock wool insulation that tucked between the studs and rafters were also available. Its application was similar to present-day fiberglass insulation except that it was thinner.

Widely advertised was "Insulex", a gypsum mixture developed in 1924 which when mixed with water would expand to five times its original volume, entraining air pockets which gave it superior insulating qualities (estimated as $1\frac{1}{2}$ to 7 times better than other products on the market). Poured between the studs, this material filled the entire wall cavity, offering a thicker insulation than almost any other material available at the time. Johns Manville in 1931 was selling a blow in rock wool insulation for use in existing houses.

Glass fiber products, mostly woven into fabrics, were developed as early as 1893. In the mid 1930's the Owens-Illinois Glass Company and Corning Glass were both exploring ways of producing glass fibers economically in quantity. By 1936 Corning was turning out glass fiber building insulation and in 1938 the Owens Corning Fiberglas Corporation was formed to produce and market these products, now the most widely used type of insulation in residences.

The amount of insulation felt to be adequate in buildings has traditionally been measured in terms of the length of time necessary for the fuel savings to pay back the added cost of the insulation. In a time when energy was plentiful and cheap no thought was given to the value of insulation at all. In the 20's an inch was considered the reasonable limit; studies did not even consider a greater quantity. Currently the

full-wall thickness of $3\frac{1}{2}$ inches is considered standard. Those advocating using construction methods allowing up to six inches of insulation cite payback periods estimated at from two to ten years.

At a time when the country is facing the very real prospect that its reserves of home heating fuels will be substantially depleted within one or two generations, this emphasis on return of investment seems terribly shortsighted. Traditionally buildings have a life span much longer than the five or ten year accepted payback period or even the life of a 40 year mortgage. Houses constructed with what was considered excessive insulation half a century ago are now deemed to be woefully inadequate in their thermal performance. Short of going to ridiculous extremes of expense, it is probably time for building performance to be judged according to how little energy is required in absolute terms, rather than by the dictates of a cost/benefit equation that may change drastically over the years.

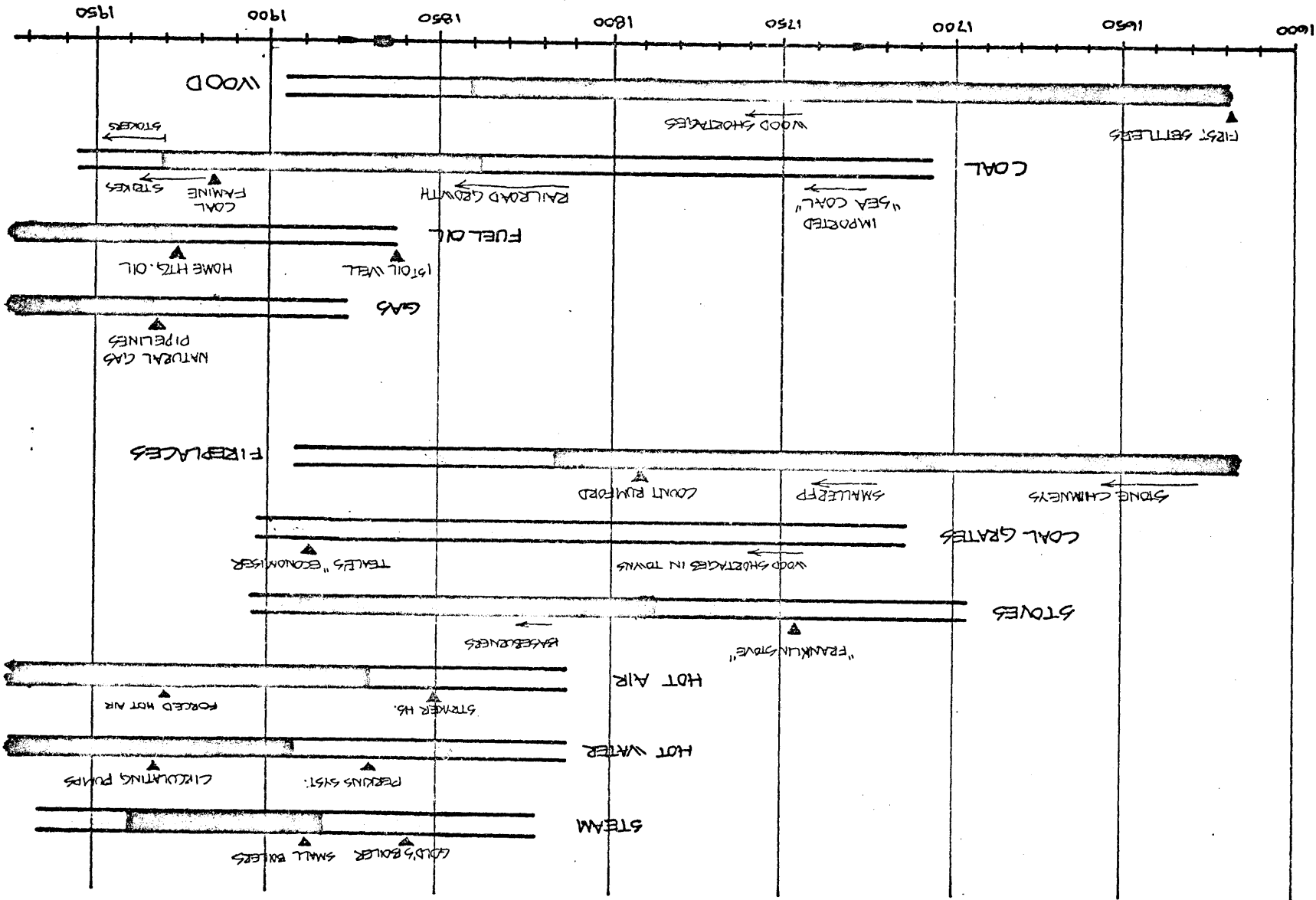
CHAPTER XI

LOOKING BACK AND AHEAD

The history of the developments of residential heating is really one of periods of change and periods of relative stability. While in some ways the particulars of those changes have differed, patterns of cause and effect emerge -- common sets of circumstances and goals that have influenced each major advance in the art of heating. Understanding these patterns is particularly useful now, as we sit poised on the brink of what ultimately must be the most profound changes in heating and energy use yet.

The evolution of heating methods has followed two parallel and interconnected lines of development: changes in the type of fuel used and changes in the extraction of heat from that fuel. In this study we have seen three major changes in the predominantly used fuel. First was the conversion from wood to coal in England. Second was the same conversion in this country around 1750 and 1850. Most recently was the turning away from coal to oil and gas in the period from 1920 to 1950.

Each of these changes was primarily the result of adverse conditions of price and supply of the fuel then predominantly in use. A secondary reason, really significant only in the case of the decline of coal use, was the desire for a fuel that in some way could be more conveniently used. There has been a clear trend throughout the evolution of heating toward removing the effort from the process of attaining warmth, just as there has been in virtually every other major advance in modern civilization (assuming that such a trend really constitutes an advance).



All of the major advances in heating, whether changes in fuel or in the modes of using it, have taken about 50 to 100 years to come about; the major exception again being the switch to oil and gas in which the factor of uncertain fuel supply was sharply reinforced by the desire for the convenience of automatic heating. In each case the new methods were first adopted by the wealthy, who could afford to experiment with something new. (Ironically, the ones who were the least affected by adverse conditions of price or supply were the first to be able to escape them.) Then would follow a period of development and expansion in which the new methods were refined and made less expensive, making them accessible to more and more people. At a certain point a threshold level of price and technical development would be reached, beyond which widespread adoption of the newer technique would be assured. Coal reached that point in the 1860's; oil and natural gas around 1930. Cast iron stoves became available to the masses early in the 1800's; hot air heating around the 1870's; steam and hot water heating between 1890 and 1900. Coal grates never reached the threshold in this country due to their slow technical development.

Another more technical pattern emerges in the development of heating equipment. This was the effort to extract the maximum amount of usable heat from the fuel as it was burned. Those efforts can further be categorized as those aimed at burning the fuel more completely and those aimed at making the most use of the heat after the fuel was burned.

Of the former the major advances have been in the area of controlling the drafts to insure more complete combustion. These can be found in Rumford's fireplace modifications, in the design of the hob grate, and later in the draft controls on furnaces and boilers. A major step was to provide thermostatic control of the drafts, eliminating the need for

keeping a watchful eye on the fire. More recently the introduction of Bunsen's principles to gas burning and of the forced draft of oil burning equipment follow the same line.

Advances in making the best use of the heat of the fire date back to Desaguliers' experiments and to Benjamin Franklin's design for the "Pennsylvania Fireplace." The latter is particularly important for it introduces the concept of extending the flue gas travel and the heating surface within the heater to gain the maximum possible transfer of heat. This principle, found in the operation of the nine-plate stove, the Mercer boiler and the Stryker furnace, among other examples, has been perhaps the most important single concern in the design of heating equipment right up to the present day. It can be found in boiler design as well as in the evolution of the mattress radiator into the modern fin-tube convector.

Looking ahead, it is becoming abundantly clear that Byrd's 1913 prophecy that "the oil will go first" is going to come true. It is ironic that coal, which the nation so speedily abandoned in its rush to the convenience of automatic heat, may prove to be the only resource that is both economically and technologically feasible as a heating fuel over the short term, whether burned in home furnaces or in central generating plants. However, there are serious questions connected with coal use that remain to be answered: Can efficient and automatic means of consuming coal in the home be perfected, and, if so, can they be brought within the economic grasp of the public? Could that changeover be accomplished before the other fuels run out? Can the trend toward increased convenience be reversed if that is necessary to insure adequate energy supplies at reasonable cost? Can the nation afford the environmental damage, both in terms of air quality and the effects of mining, that large-scale use of coal will surely require?

For the long term, it must be recognized that even the supply of coal is limited, and that eventually other sources of heating energy must be developed. Of the possible alternatives that can be seen today, the most attractive is probably some form of solar or solar-assisted heating. But any widespread conversion to solar heating probably involves more fundamental changes than has any previous change in heating method.

As discussed in Chapter II, American residential architecture turned away from essentially climatological responses in house design. Ever since then the design of the houses that most people live in has been based more on fashion than on the essential function of providing shelter and warmth. The history of the application of heating methods has been typically the retrofitting of new equipment into old houses and house designs. There is little evidence to indicate that different methods of heating have greatly influenced the form that the dwelling has assumed after the passing of the traditional colonial house with its huge central fireplace.

That is a situation that must change if solar heating methods are to come into widespread use, for a thermally efficient house must work in harmony with the forces of nature and not defiantly confront them. It is here that the past provides some suggestions for building houses that not only are efficient in their utilization of energy but also that maintain an historical link with traditional ways of building and living.

The model for such a New England house of the future would be the classic central-chimney house with a lean-to at the northern side. The size, proportions and general appearance of this house might be very similar to that of the John Dillingham house (Fig. 18) or the Jethro Coffin House (Fig. 16), but with greatly increased fenestration on the south facade to increase winter solar heat gain. The south-facing slope

of the roof could be covered with solar collectors and the massive central chimney might find its latter-day expression in the form of a vertical heat-storage chamber through which all the heat-producing appliances in the house would ventilate in a manner similar to that in Catharine Beecher's American Women's Home. Constructed by modern methods (the central storage mass might be made up of precast concrete caisson sections, for example) such a house would be not merely a replica but a distinctly New England response to the problem of keeping warm in the twenty-first century.

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